中華農業研究

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Jojoba 之生長習性及開花形式[1]

邱　善　美[2]

摘要：本試驗之目的在瞭解 Jojoba (*Simmondsia chinensis* [Link] Schneider) 植株生長習性及開花現象。結果顯示，在 50 株供試材料中，具生長習性爲平伏式 (Prostrate) 者及多葉式 (Leafy or compact) 者各 1 株，其餘48株均爲開放式 (Open) 。葉之大小，形式及節間長度，各形式間都有顯著的差別。

休眠性雄花芽在種子萌芽後７－８個月即可形成。雌性休眠花芽約較晚 ２－３ 個月。不論是雄性或雌性的休眠性花芽，開花期槪在寒冷之秋冬季節，未開花者則仍呈休態眠狀。

雄花的開花有二種迴然不同的現象：（１）在雄株的植株上先形成由數個花苞聚集在一塊之休眠性花芽而後在秋多季開花。（２）每一花苞單獨形成，不呈聚集狀，無顯明的休眠期，開花後可顯明的看到花萼５片及雄蕊８枚。

Jojoba (*Simmondsia chinensis* [Link] Schneider) 屬黃楊科 (Buxaceae) Simmondsia 屬。原產於美國亞利桑那州及加州的南部，墨西哥的北部 Sonoran 沙漠地區，係一種多年生常綠灌木，其生命力可達 100 至 200 年之久 (4)，株高最高者可達 15 呎，一般甚少超過 10呎，雌雄異株 (4,6)。種子含油脂量高達50%左右。

遠在 1701 年前，當地的印第安人 (Pima Indians) 已知用其油脂爲醫藥、生髮劑、催生劑、化粧品及食用油等用途，並以其種子磨碎做成類似咖啡的飲料 (1,2,4,5)，然在此時期其利用價值尚未受重視，迄 R. A. Greene 和 E. O. Foster (1933) 分析其成分，始發現其油脂成分及結構與工業上所不能缺乏的抹香鯨油 (Sperm whole oil) 極相似，因而乃有欲藉此油脂取代抹香鯨油，以挽救抹香鯨面臨絕種危運的構想。

Jojoba 種子所含之油脂（實際上是一種流質臘，Liquid wax (1)）性質不易氧化而穩定，能吸收較多分子硫化物而仍能保持流質，在重複高溫高壓下不喪失其粘度，爲理想的高級潤滑油，對機械性能的維護極佳，同時並可做爲汽油的添加劑，可以提高汽車行駛里程的 25% (2)，此外，尙可提煉盤尼西林、製藥丸外衣、淸潔劑、車臘、地板臘、合成纖維、合成塑膠及塗料等石化工業原料，用途極廣，因此有人稱它是1990年的搖錢樹 (2)。

本試驗之目的在瞭解此一新興植物的生長習性及開花現象。謹將初步觀察結果，撰成報告，藉以供有興趣的同仁參考，並向引入者屈技正先澤先生誌最深的謝意。

材料與方法

本試驗所使用之種子，係民國69年自美國加州引入。全部試驗分二個播種期，第一次播種於69年７月中旬，播種於 32×15 cm 之磁缽中，每試缽播種１粒，計20個試缽。土壤取自本所試驗農場，屬

1.臺灣省農業試驗所　研究報告第1086號。本計畫部分經費承農發會補助（71農建—41—產32）。
3.本所農藝系副研究員。臺灣省　臺中縣　霧峰鄉。

沙質壤土，未施任何基肥或堆肥，播種後即置於玻璃溫室中培育，發芽後計獲得植株19株，爾後計施化學肥料3次，每次施用硫破，過磷酸石灰各2克及氯化鉀各1克，每星期六灌水1次。第二次播種期爲70年3月上旬，分別播於田區及溫室試缽（型式大小同前），肥培及其他管理方法概與上次相同。計播於田區者獲得97株，植於玻璃室者獲得31株，連同上年（第一次播者）之19株，合計50株供作本試驗觀察之材料。

結果及討論

一、植株生長習性　就極有限的50株材料，觀察其個體間生長習性之結果，可區分爲下列三種迴然不同的生長型式（圖1－3）。

(一) 平伏式（Prostrate）　在50個單株中僅發現1株，植株平伏，生育初年未發現有直立的支幹，葉呈橢圓形，平均葉寬 1.9 cm，葉長 4.5 cm，節間長 4.0 cm，二年生之植株仍未具開花現象（圖1）。

(二) 多葉式（Leafy or Compact）　分枝多，葉數多，節間短爲其特色，平均葉寬 1.7 cm，葉長 3.7 cm，呈腎臟形，節間長2.5 cm，在全部試驗材料中亦僅發現1株，亦尚未具開花現象（圖2）。

(三) 開放式（Open）　植株直立生長，枝條少，平均葉寬 2.8 cm，葉長 5.1 cm，節間長3.1 cm，雌雄花芽顯現期早，在供試之材料中，以此一形式的植株所佔比率最多（圖3）。此結果與Demetrios M. Yermanos [6] 在加州所調查之結果甚爲符合。本次所引入的種子或可能係一個雜質體。

二、雌雄花開花現象　雌雄異株（Dioecious），但雌雄同株之植株也曾被發現過 [4]。在本次供試之材料中顯示，雄花的形成及開花有二種迴然不同的現象，其一，係種子萌芽後7－8個月，在當年生之枝條上，即可形成休眠性的雄花芽，此花芽係由數個花苞聚集成一腫瘤狀，呈青綠色，表面凹凸不平，具長柄（圖4）。俟氣溫下降後至秋冬季節始行開花，花形成聚集狀，外形類似菊花之花（圖5），各具花萼5片，花金黃色，以指觸之即有大量黃色花粉落下。其二、雄花芽在冬季寒冷季節形成，隨之開花，沒有明顯的休眠期，每一花苞個別獨立形成，不呈聚集狀（圖6）開花時具有明顯的花萼5片，雄蕊8枚，無花瓣（圖7）。

休眠性雌花芽的形成概較雄花芽爲晚2－3個月，如甕形，青綠色（圖8）開花時具三個花柱及花萼5片（圖9）。開花期亦在寒冷之秋冬季。

綜上結果，不論是休眠性的雄花或雌花，開花期概在秋冬季，而以寒冷的冬季爲盛，如在此時期所形成的雄花可直接開花（無顯明的休眠期）。未開放的休眠性花則仍呈休眠狀態，此現象與Gentry（1958）及 Dunstone（1980）所獲結果相似，但在該等報告中並未提到花苞有個別開花的特性（圖6－7），致使此種現象發生的原因是否是由環境因子所導致之結果不甚瞭解。其次，就觀察其植株生長情形，著果形態而言，每株朔果產量不會太高，幸好在自然界中亦發現有 multiple fruit [6] 的現象，可能有助於今後選種工作。

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Growth Habits and Flowering Pattern of Jojoba[1]

S. M. Chiu[2]

Summary

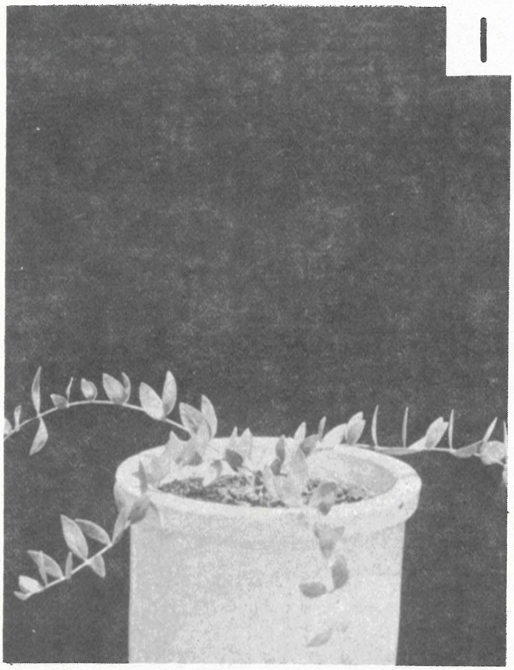
The growth habits and flowering pattern of jojoba (*Simmondsia chinensis* (Link) Schneider) were observed in the green house at TARI, Taichung, during the period from 1980 to 1981. Three types of growth habit were found among 50 plants : One each of prostrate and leafy (or compact) types, and the rest open type. Leaf shape, leaf size and internode length on the main stem varied according to the different type of growth habit.

The dormant male flower buds appeared when plants were 7 to 8-months old, whereas the female ones formed 2-3 months later. Both male and female dormant flower buds blossomed only in autumn or winter and un-opened ones remained dormant.

Two types of blossoming were observed on male plants : (1) dormant flower buds formed in clusters and blossomed in autumn or winter and (2) single flower buds, with no dormant period, came in to full blossom with 5 sepals and 8 stamens.

1. Contribution No. 1086 from Taiwan Agricultural Research Institute.

2. Agronomist, Department of Agronomy, TARI, Wufeng, Taichung Hsien, Taiwan 431, ROC.



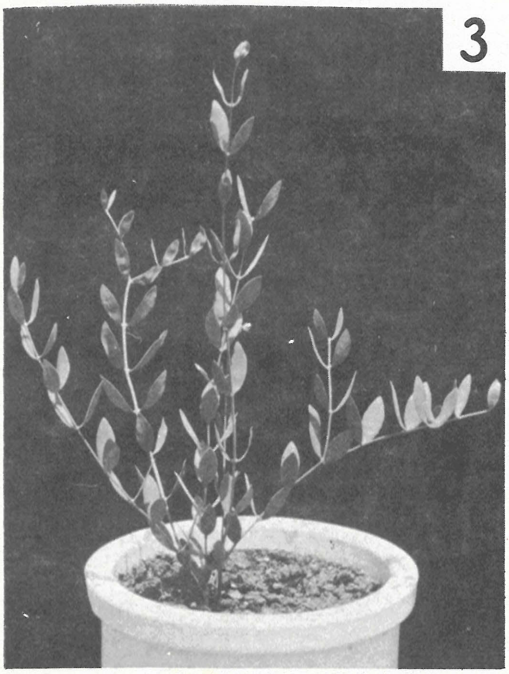
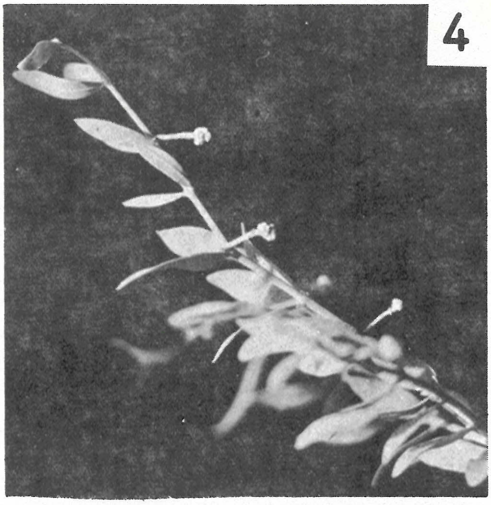


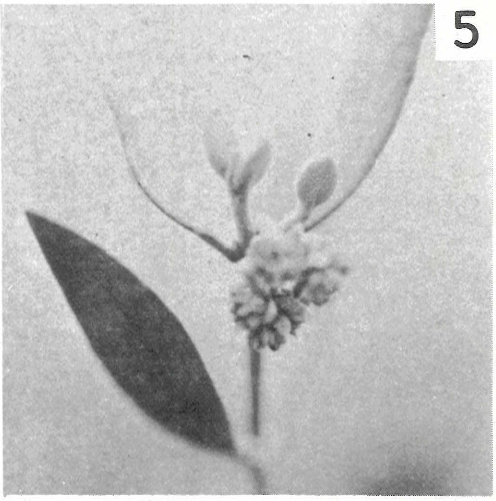
Fig. 1. Types of growth habit of jojoba.

(1) Prostrate

(2) Leafy or Compact

(3) Open





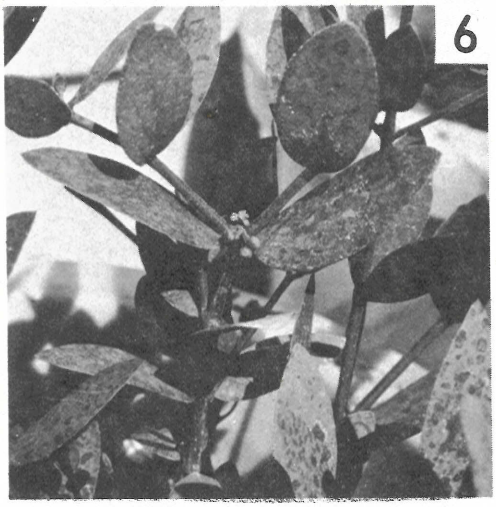
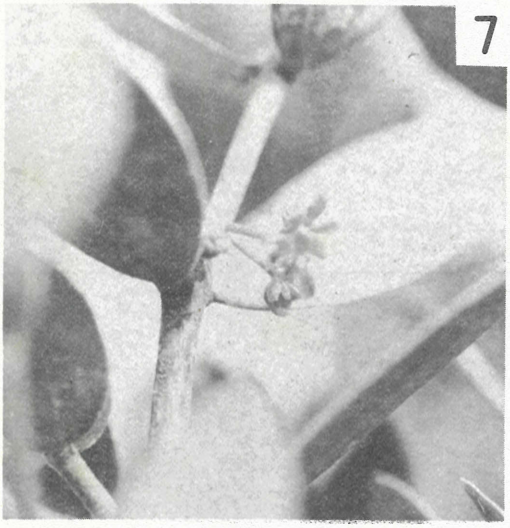


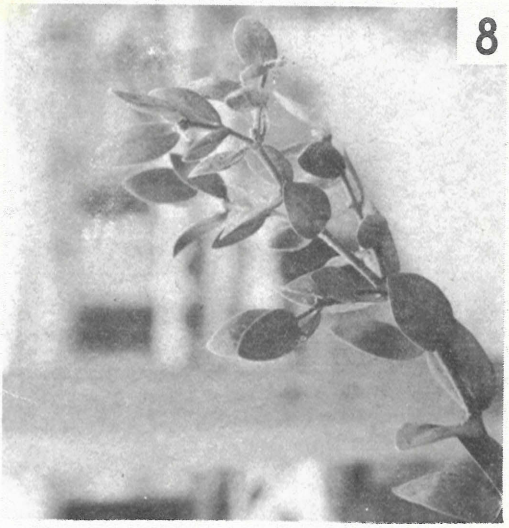
Fig. 2-A. Flowering pattern of iojoba.

(4) Dormant male flower buds.

(5) Clustered male flowers.

(6) Individual male buds.





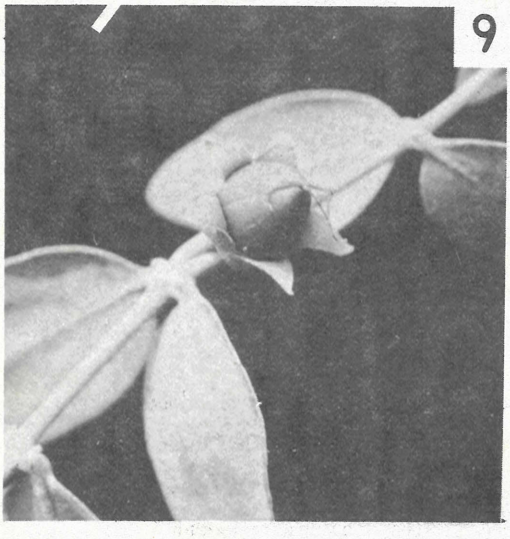


Fig. 2-B. Flowering pattern of jojoba.

(7) Blooming male flowers with 5 sepals and 8 stamens.

(8) Dormant female flower buds.

(9) Blooming female flower.

(Jour. agric. Res. China) 中華農業研究32(2)：111~121 (1983)

Studies on the Efficiency of Alcohol Production in Sweet Potato, Cassava, and Potato[1]

Sin-Yie Liu and Chun-Ling Liang

Abstract: Three starchy crops, sweet potato, cassava, and potato, were used to study the efficiency of alcohol production. The results are summarized in the following.

(1) The alcohol yield of starchy crops depends not only upon the starch content, but also on the hectare yield, water content, growth period, and the degree of starch purification.

(2) The simplest method for saccharification and fermentation is to mix the starch material with yeast (Saccharomyces cerevisiae), α-amylase solution, and distilled water at the beginning of the process. It saves energy, as well as labor costs.

(3) Using this method, an alcohol yield of 5.9% for sweet potato, 7.5% for cassava, and 5.2% for potato can be obtained. If purified starch is used, the following alcohol production rates can be reached: sweet potato 9.9%, cassava 10.5%, and potato 9.5%. In the last five years, the hectare yields were averaged 16.0 tons for sweet potato, 15.4 tons for cassava, and 11.7 tons for potato. If calculation is based on purified starch, the following amounts of alcohol per ha can be distilled: 1,856 1 (liter) from sweet potato, 2,296 1 from cassava, and 760 1 from potato. During the purification process, a large amount of material is lost. If this loss is minimized, the alcohol yield from purified starch can be increased by as much as 1.40—1.83 times.

(4) Under local cultivation conditions, sweet potato can be planted in the spring, summer, and autumn, cassava in hilly areas, and potato in winter. Particular attention should be paid to sweet potato, which is more efficient in alcohol production than the other two. However, in case of emergency, all three starchy crops could be used as substitute energy resources.

With petroleum prices increasing at a rate faster than prices of agricultural products, the benefit from food crops export to interchange for fuel petroleum has decreased. In recent years, the use of agricultural products to produce alcohol for fuel has gained worldwide interest. Several economic studies, on the feasibility of growing crops to provide starch for fermentation into alcohol were resulted in optimistic to pessimistic conclusions.

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1. Contribution No. 1087 from Taiwan Agricultural Research Institute.

2. Agronomist and assistant, respectively, Department of Agronomy, TARI, Wufeng, Taiwan, R. O. C.

Alcohol is a very useful liquid fuel. When mixed with petroleum (10% anhydrate alcohol+90% no Pb petroleum), it is called gasohol. Diesohol is a mixture of alcohol and diesel oil. Both have been used in some other countries.[3,9]

In Taiwan, 98% of the petroleum, and 82% of total energy needs are imported.[9] In the event of another energy crisis, renewable energy, including liquid alcohol, will play an important role. Thus, the question of which material is most economical for alcohol production is raised. In Taiwan, sweet potato, cassava, potato, sorgo,[3,11] leucaena,[4] sugar cane,[3,8] and giant brown kelp,[9] etc. all have the potential to meet this purpose. Since sweet potato, cassava, and potato are fast growing and high yielding starch crops in this province, they are to be considered as potential alcohol producing crops. Therefore, it is necessary to evaluate the efficiency and economics in alcohol production for these three plant species.

Materials and Methods

I. Materials

1) four sweet potato lines (C65, C65—46, C65—319, and C65—356)
2) three cassava varieties (Gie-tze-zong, Bai-gu-tze, and I-tze-shiang)
3) five potato lines or varieties (77—054—164, Cardinal, 325, 272, and 16)

II. Methods

1) Analysis of the chemical composition

The water content of the material was determined by heating for three hours at 105°C, the starch content by acid-catalyzed-hydrolysis, amylose content by the automatic amylose determination method, and the shape of the starch grains by microscope at 400X power.

2) Purification of the material

The raw materials were ground, and then filtrated. The protein surrounding the starch grain was removed by 0.2—0.3% NaOH solution. Finally, the fat of the material was removed by 85% methanol solution, leaving purified starch.

3) Saccharification of starch

0.1% and 1.0% α-amylase solution were used for starch saccharification at 38°C, and the two methods of saccharification (acid-catalyzed-hydrolysis with 2.5 % HCl solution, and enzyme-catalyzed-hydrolysis with 1.0% α-amylase solution) have been compared. The glucose content was then determined by the SOMOGYI method.

4) Combination of saccharification and fermentation[13].

A 50ml mixture was made, containing 10g of unpurified starch, 1.0% α-amylase solution from Aspergillus oryzae (6,500 U. E./ml), Saccharomyces cerevisiae (500mg), and distilled water. Citrate was added to adjust the pH-value to 3.5. This starch solution was subsequently fermented at 38°C. The process was also repeated in an identical fashion using purified starch.

5) Determination of fermentation rate and alcohol production rate

Einhorn fermentation tubes were used to determine the CO_2 quantity in order

to find out the fermentation rate. The ethanol alcohol content was determined by G. C. under the following conditions: column temperature of 140° C, injection temperature of 160°C, detector F. I. D. temperature of 160°C, and an H_2 flow rate of 40—50ml/minute.

Results

I. Gross composition of sweet potato, cassava, and potato

The average water contents of sweet potato, cassava, and potato are 67.0%, 61.9%, and 78.4%, respectively (Table 1).

Starch contents on a dry weight basis were found to be 63.4%, 70.0%, and 54.0%, respectively.

Except for special varieties (Cardinal and C65), the difference in amylose content was not very great (sweet potato-12.6%, cassava-14.1%, and potato-16.0%). No close relationship between starch and amylose contents was found.

Furthermore, nearly all the starch grains were spherical or spheroidal in shape.

Table 1: Gross composition of sweet potato, cassava, and potato starch

Variety or Line	Moisture (%)	Starch (% d. w.)	Amylose (% d. w.)	Granule shape
A) sweet potato				
C65	70.8	60.4	8.5	oval, spherical
C65—46	66.4	68.9	13.0	oval, spherical
C65—319	67.7	63.4	14.1	oval, spherical
C65—356	62.9	60.6	14.8	oval, spherical
Average	67.0	63.4	12.6	oval, spherical
B) cassava				
Gie-tze-zong	53.6	69.8	15.0	oval
Bai-gu-tze	69.4	72.4	13.1	oval
I-tze-shiang	62.6	67.8	14.1	oval
Average	61.9	70.0	14.1	oval
C) potato				
77—054—164	75.0	60.9	17.0	oval
Cardinal	76.5	62.8	19.5	oval
325	77.1	53.9	15.4	oval
272	81.4	47.2	15.5	oval
16	82.0	45.2	12.7	oval
Average	78.4	54.0	16.0	oval

II. Saccharification of starch

Two α-amylase solutions, 0.1%, and 1.0%, were compared. After 17.5 hours, the cassava saccharification rate of the 0.1% α-amylase solution reached 5.0% and after 41.5 hours, 5.6%. With the 1.0% α-amylase solution, they reached 29.4% and 39.2%, respectively. Therefore, the 1.0% α-amylase solution had an effect six times as great as the 0.1% α-amylase solution.

In potato, the effect of the 1.0% α-amylase solution was approximately five times as great as the effect of the 0.1% α-amylase solution. (Table 2)

Table 2 : Effect of enzyme concentration on saccharification

Enzyme and Substrate	Saccharification rate (%)	
	17.5 hr	41.5 hr
A) 0.1% α-amylase solution		
cassava starch	5.0	5.6
potato starch	9.7	10.6
B) 1.0% α-amylase solution		
cassava starch	29.4	39.2
potato starch	51.0	58.4

The results of the two saccharification methods (acid-catalysed-hydrolysis with 2.5% HCl solution and enzyme-catalyzed-hydrolysis with 1.0% α-amylase solution) have also been compared. In both methods, 0.5g of cassava starch was used. Using a 2.5% HCl solution, 88% of the starch could be changed into glucose within four hours.

When a 1.0% α-amylase solution was used, a saccharification degree of only 30% was reached after two days. In neither case could the saccharification amount be increased through longer incubation. Under the first method, 20 samples cost NT$140, while the second method, NT$144 (Table 3).

Table 3. Comparison of two saccharification methods

Methods	Cassava starch (g)	Reaction rate (% hr^{-1})	Total expense for 20 samples
Acid-catalyzed-hydrolysis (2.5% HCl)	0.5	22.01	N.T.$ 140.8
Enzyme-catalyzed-hydrolysis (1.0% α-amylase)	0.5	0.63	N.T.$ 144.4

III. Alcohol yield of sweet potato, cassava, and potato starch

Among the four sweet potato lines tested, line C65—46 had the highest starch content and alcohol production rate of 23.16% and 6.06%, respectively, followed by C65—356, with 22.50% and 5.93%, C65—319 with 20.48% and 4.51%, and C65 with

17.64% and 4.12%, respectively (Table 4). There was a positive correlation between starch content and alcohol production rate (r=0.895).

Table 4. Alcohol production % (V/TV) of four sweet potato lines

Line	Starch content (% f. w.)	Alcohol production rate
C65	17.64	4.12
C65—46	23.16	6.06
C65—319	20.48	4.51
C65—356	22.50	5.93

Among the three cassava varieties (Gie-tze-zong, Bai-gu-tze, and I-tze-shiang), variety Gie-tze-zong, with a starch content of 32.4% was the highest, produced the largest amount of alcohol (7.81%). Variety I-tze-shiang, with a starch content of 25.4%, produced the second highest alcohol amount (7.49%). Variety Bai-gu-tze, with a starch content of 22.2%, produced 7.28% alcohol (Table 5). A highly positive correlation (r=0.991) between starch content and alcohol production rate could be realized.

Table 5. Alcohol production % (V/TV) of three cassava varieties

Variety	Starch content (% f. w.)	Alcohol production rate
Gie-tze-zong	32.4	7.81
Bai-gu-tze	22.2	7.28
I-tze-shiang	25.4	7.49

Among the five potato lines or varieties analysed, line 77-054-164 with a starch content of 15.2%, had the highest alcohol production rate 6.20%. Line 16, which had the lowest starch content of 8.1% reached only an alcohol production rate of 1.37%. (Table 6) A positive correlation of 0.941 between starch content and alcohol production rate could also be realized.

Table 6. Alcohol production % (V/TV) of five potato lines or varieties

Variety or Line	Starch content (% f. w.)	Alcohol production rate
77—054—164	15.2	6.20
Cardinal	14.8	5.20
325	12.4	4.53
272	8.8	2.79
16	8.1	1.37

The alcohol yield of a single plant does not only depend upon its starch and water content, but also upon its yield. For example, the variety "Cardinal", with a starch content of 14.8%, had nearly the same alcohol yield as line "325", which had starch content only 12.4%. This is because variety "Cardinal" had a yield of 700g per plant as compared with 770g in line "325" (Table 7).

When purified sweet potato starch (from line C65—356) was used, the alcohol production rate reached 9.9%, as compared with the 5.9% of unpurified starch. The alcohol rate produced from purified cassava starch (from variety I-tze-shiang) amounted to 10.5%, as compared with the 7.5% of the non-purified starch. In potato (from variety "Cardinal") the alcohol production rate amounted to 9.5% for the purified starch, and 5.2% for the unpurified starch. Obviously, when the starch was purified, the alcohol rate was much higher than that of the non-purified starch. There is a highly significant correlation between starch purification and alcohol yield (Table 8).

Table 7. Theoretical alcohol production per hectare of five potato lines or varieties

Variety or Line	Starch content (% fr. w.)	Moisture (%)	Alcohol (ml/10g starch)	Yield (g/pl.)	Theor. ha Alcohol(1)
77—054—164	15.23	75.0	3.29	562	1,541
Cardinal	14.78	76.5	2.59	700	1,420
325	12.36	77.1	2.40	770	1,411
272	8.80	81.4	1.48	271	228
16	8.14	82.0	0.28	672	113

Table 8. Effect of starch purification on alcohol production rate

Energy crop	Starch content (% d. w.)		Alcohol production (% V/TV)	
	non-purified	purified	non-purified	purified
sweet potato	60.7	89.3	5.9	9.9
cassava	67.8	88.2	7.5	10.5
potato	62.8	88.4	5.2	9.5

Using 10g unpurified sweet potato dry starch (from line"C 65—356"), an alcohol yield of 5.9%, i. e. 3.13ml, was produced. In the past five years (1976—1980), the average sweet potato ha-yield was 15,979 kg/ha (Table 9). After subtracting the water content (62.9%) from the ha-yield (Table 1), 5,928kg unpurified sweet potato starch was obtained, and theoretically, from this, 1,856 l of alcohol could be produced.

Table 9. The annual yield of sweet potato, cassava, and potato from 1976—1980 in Taiwan

Year	Yield per hectare (kg)		
	sweet potato	cassava	potato
1976	14,959	16,291	11,082
1977	15,551	15,581	11,361
1978	15,964	15,008	11,623
1979	16,476	15,305	12,339
1980	16,949	14,941	12,170
Average	15,979	15,425	11,715

With an average hectare yield of 15,425kg, and a water content of 62.6%, 5,769 kg unpurified starch from cassava variety "I-tze-shiang" could theoretically yield 2,296 l of ethanol alcohol.

From potato variety "Cardinal" with an average hectare yield of 11,715 kg and a water content of 76.5%, 2,753 kg unpurified starch could be produced. This, in turn, could theoretically yield 760 l of alcohol.

IV. Factors influencing the fermentation rate and alcohol yield

a. Effect of starch purification on alcohol production

Purified sweet potato starch produced 1.70 times as much ethanol as non-purified starch. Purified cassava starch yielded 1.40 times as much alcohol as unpurified starch. For potato, it was as much as 1.83 times.

b. Effect of pH-value on the fermentation rate

Under acidic conditions (pH 2.5—4.5 adjusted by citrate or phosphoric acid), Saccharomyces cerevisiae performed better than under neutral conditions (pH 5.5 —7.0).

c. Influence of the starch concentration on the fermentation rate

To each starch concentration, 0.5g yeast was added. The quickest fermentation rate was obtained by using 5.0g starch/50 ml volume. When a concentration of 0.5g starch/50 ml volume was used, the amount of alcohol was only 12.9% of the 5.0 g starch/50 ml volume, with a concentration of 1.0g starch/50 ml volume, it was 24.5% of the 5.0 g starch/50 ml volume, and with 10.0 g starch/50 ml volume, it was 61.8% (Table 10). Using a higher starch concentration than 10.0 g starch/50 ml volume, the rate of ethanol production decreased because of the increasing difficulty in mixing starch grains, amylase solution, and yeast.

Table 10. Fermentation rate (indicated by CO_2 production) from different amounts of potato starch (using acid-catalysed-hydrolysis and adding 0.5g yeast)

Potato starch (g)	CO_2 production (ml)					Index (%)
	1hr	2hr	3hr	4hr	5hr	
0.5	0.60	0.80	1.25	2.25	2.35	12.9
1.0	0.80	1.30	2.25	3.65	4.45	24.5
5.0	2.00	3.50	6.60	13.90	18.20	100.0
10.0	0.60	1.30	2.95	6.95	11.25	61.8

d. Effect of S. cerevisiae quantity on the fermentation rate

When purified sweet potato or cassava starch were used, the alcohol fermentation rate was increased by larger amounts of yeast.

Discussion and conclusion

Sweet potato, cassava, and potato starch can be saccharified and fermented to produce ethanol alcohol. [3,8,9,10,13] In this study, a higher ethanol production rate (7.5% V/TV) was obtained by using cassava starch than by sweet potato (5.9%) or potato starch (5.2%).

For a high alcohol yield, a high starch content in the plant is the most important criterion. For example, the two potato lines, 77-054-164 and 16, have starch contents of 15.23% and 8.14%, respectively, and from that, an alcohol yield of 1,541 l/ha and 113 l/ha, respectively, could be obtained. The substantial difference is due to the difference in starch content. Varietal variation in starch content within a plant species was obtained : The starch content of sweet potato varied from 8% to 29%, cassava from 22% to 32%, and potato from 8% to 22%. Therefore, varieties with the highest starch contents should be used for alcohol production, and the development of high starch content varieties through breeding should be emphasized.

On the other hand, the growth period of a plant species is equally important. Though the estimated ethanol yield in cassava is as high as 2,296 l/ha, compared with sweet potato's 1,856 l/ha, and potato's 760 l/ha, it must be taken into consideration that cassava's growth period lasts 15—18 months. [14] Potato has a growth period of only three months, but its alcohol yield is low, due to its high water content and low average ha-yield. Furthermore, potato, a cold weather crop, can be planted only once in the winter in Taiwan [12]. Among the three plant species, sweet potato is the most efficient energy crop. Although its alcohol yield of 1,856 1 is lower than that of cassava, its average ha-yield is higher, in addition, it can be planted two or three times a year [6].

The water content and the yield capacity of tubers are the essential criteria for determining alcohol production levels. The estimated ethanol ha-yield of potato variety "Cardinal" was as low as 760 1, which is only 60% of the amount reported previously [3]. This was primarily due to this variety's high water content. Its ethanol hectare yield

was calculated by averaging the 5-year yield of all potato varieties. If the yield per plant of 700g (Table 7) had been used, an ethanol yield of about 1,420 l/ha could have been obtained. This means the higher the ha-yield of the variety, the higher the amount of alcohol produced.

The theoretical ethanol yields of sweet potato and cassava reported from others are 1,875 l/ha and 2,700 l/ha (3), and 1,758 and 2,567 l/ha (9) respectively. These values are very close to the present study's findings of 1,856 and 2,296 l/ha, respectively.

By using NaOH and methanol solution, a purification grade of 90% was obtained (Table 8). This purification process has two advantages : a shorter fermentation period, and a higher alcohol yield. As shown in this study, the purified sweet potato starch produced an alcohol yield 1.70 times greater than that of non-purified sweet potato starch (Table 8). The same effect was observed on cassava, which was as high as 1.40 times, and on potato, as high as 1.83 times. But, during the purification process, a lot of material was lost. It is very important to minimize this loss.

Saccharomyces cerevisiae performs better under acid than neutral conditions, but whether citrate or H_3PO_4 was used made no difference.

Other factors which can affect the results of fermentation are : the fermentation temperature, the removal of inhibiting substances, the agitation of the fermentation tube, and the yeast species (11,13) etc. For example, the yeast species, Zymomonas mobilis, and Saccharomyces formosensis, had positive effects on the fermentation of sorgo (11). It has yet to be determined whether these two yeast species also have positive effects on sweet potato, cassava, and potato.

In addition to the use of sweet potato, cassava, and potato tubers for ethanol production, their leaves and stems can be used to produce methane gas (2,3). This aspect should be further studied.

With regard to energy input and output(energy balance)in sweet potato and cassava ethanol production, Prof. Y. C. SU reported that both had a net gain of 760 Kcal (9). If farming methods and fermentation techniques could be improved, the net energy gain could be as much as 3,260 Kcal.

Other plant species, such as sorgo, leucaena, sugar cane, etc. could be used for partial gasoline substitutes (3,9). Under local cultivation conditions, they all l ave high yield potential.

The saccharification reaction time was short when HCl solution was used for saccharification, then yeast was added for fermentation, but the alcohol yield was low. This is because the starch concentration was greatly diluted after acid treatment, and this resulted in low glucose concentration (8). If starch material, α-amylase solution, yeast, and water are mixed for both saccharification and fermentation, the process is not only energy, but also labor saving, as it was indicated in this experiment.

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甘藷、樹薯及馬鈴薯之酒精生成效益研究[1]

劉新裕　梁純玲[2]

摘　要

甘藷、樹薯及馬鈴薯等三種澱粉作物之酒精生成效益之研究結論摘要如下：

1. 影響澱粉作物酒精生成的要素，不僅在其澱粉含量，其他關係亦大的性狀尚有公頃產量、含水率、生育日數及其澱粉的純化程度。
2. 最簡便的酒精生成法是於操作開始時，混合定量之澱粉原料、澱粉酵素、酵母菌及蒸餾水，使能同時進行醣化及醱酵兩作用，此法同時可節約能源及人力。
3. 利用上法所得之酒精產率，在甘藷爲5.9%，樹薯爲7.5%，馬鈴薯爲 5.2%，如改用純化過的澱粉，則可得的酒精率在甘藷是9.9%，樹薯是10.5%，馬鈴薯爲9.5%；依過去五年的平均公頃產量，甘藷約16.0公噸，樹薯15.4公噸，馬鈴薯 11.7公噸，由之估計每公頃酒精生成量，在甘藷爲1,856公升，樹薯2,296公升，馬鈴薯760公升。澱粉於純化過程中雖量的損失頗大，但純化後其酒精產率可提高爲同量未純化澱粉的1.40—1.83倍。因此，如能改進其純化過程，使澱粉損失量減少，則酒精產量可以大爲提高。
4. 依本省的栽培狀況，甘藷可於春、夏、秋三季依序種植，樹薯可種於山坡地，馬鈴薯可於冬季種植，論酒精生成的經濟效益，甘藷的潛力凌駕於其他二者之上。

總之，這些澱粉作物在非常時期將可被用爲一種替代能源。

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1. 臺灣省農業試驗所　研究報告第1087號。
2. 本所農藝系副研究員、研究助理。臺灣省　臺中縣　霧峰鄉。

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水稻農藝性狀取樣方法之研究[1]

I. 期作間之比較

劉　清　　何　惠　　曹紹徽[2]

摘要：本文探討在不同期作下，試區取樣時水稻重要農藝性狀之適當取樣單位及樣品大小，並作產量構成要素與實粒重關係之比較。以臺農67號爲材料，分70年二期作與71年一期作調查株高、實粒重及產量構成要素等12個性狀，並作①取樣單位間與取樣單位內變異性之比較，②取樣單位大小之影響，③取樣大小之影響及④實粒重與其他性狀之相關。結果顯示一、二期作各性狀取樣單位內之變異較取樣單位間之變異爲大，且取樣單位間之差異達極顯著，表示試區內之植株間仍有某種程度之變異。除產量外，相鄰四株（2株×2株）之取樣單位可應用於一期作，而相鄰四株（2株×2株）或相鄰六株（2株×3株）之取樣單位較適於二期作。樣品大小在一期作時每試區內3個取樣單位已足够，二期作時每試區內4個取樣單位較準確。試區內之偏性因素除應盡力控制外，尚應盡可能在試區內逢機取樣，以使可能導入試驗結果之偏性因素能有機會互相抵消。實粒重與穗數之相關極高（一期作0.74，二期作0.81）但與每穗穎花數，結實率及千粒重等「導出性狀」（derived character）之相關很低，因此作選拔或作產量預測時應以 4 個產量構成要素之乘積作指標，而不能以前述導出性狀爲依據。

取樣方法爲探討如何自族羣中選出一部分個體而又能正確的代表整個族羣。取樣方法視研究目的，材料性質，時間，經濟，人力物力等條件而定。如欲加以取樣之族羣爲田間試驗之試區（plot），則此種取樣即稱爲試區取樣（plot sampling）(Gomez, 1972)。好的試區取樣法能使樣品平均值極爲接近整個試區平均值，而無需一一測量整個試區內之每一個體。實施取樣前首先需決定：（1）取樣單位（sampling unit），即欲加以測量之單位。水稻田間試驗之取樣單位可爲單株，相鄰數株或數平方公尺面積等。（2）自試區中選取取樣單位之方法，如情況許可，應盡可能採逢機取樣（Steel and Torrie, 1980）。（3）樣品大小（sample size），即欲自每一試區中選出之取樣單位數目。取樣方法爲影響試驗結果之重要因素之一，目前研究水稻的試驗者對水稻各性狀之取樣單位及樣品大小，多依個人習慣或方便取樣，缺乏理論或實驗依據，故常造成樣品過大，浪費人力及時間；或樣品過小，取樣單位太小，以致所獲資料缺乏代表性。本研究之目的乃欲探討在不同期作下，水稻重要農藝性狀之適當取樣單位及樣品大小，以供各試驗者進行水稻試驗之參考，俾減少不必要之勞力及時間，並增加試驗結果之可靠性及代表性。

材料與方法

1.試驗材料：試驗材料爲臺農67號，試驗於70年二期作及71年一期作在臺中縣霧峰鄉臺灣省農業試驗所試驗田進行，生育期間曾加適時之病蟲害防治，田間管理及肥料用量按一般慣行法實施。

2.試驗方法：①本研究爲探討取樣單位及樣品大小對各農藝性狀變異性（variability）之影響，故在1000平方公尺之試驗田中，以相鄰九株爲一取樣單位，逢機選取 100 個取樣單位組成樣品，族羣

1.臺灣省農業試驗所　研究報告第1088號。本計畫承行政院農業發展委員會補助，謹致謝忱。

2.本所農藝系研究員、助理研究員、助理。臺灣省　臺中縣　霧峰鄉。

取樣率（sampling fraction）約爲 $^1/_{10}$。調查及記錄各性狀時仍以株（hill）爲單位，以便研究取樣單位大小之影響，各性狀依各生長時期進行取樣並調查記錄。②資料分析：在不同大小之取樣單位（由1株至九株）下，分析樣品取樣率（100% 至5%）與各性狀變異性之關係，並配合取樣單位間與取樣單位內變異性之比較，決定最適當的取樣單位及樣品大小。

3.調查項目：株高，穗數，穗重，穗長，實粒重，總粒重，實粒數，空粒數，每穗穎花數，結實率，千粒重，實粒重／穗重等 12 個性狀。各性狀之定義及調查方法均按國際稻米研究中心出版之「The Morphology and Varietal Characteristics of the Rice Plant」一書行之。

結 果 與 討 論

(一) 取樣單位間與取樣單位內變異性之比較

由各性狀資料單分類變方分析結果，可比較取樣單位間與取樣單位內變異性之大小。若取樣單位間之變異不顯著，則表示整個試區可視爲一同質（homogeneous）性的羣體，因此取樣單位之數目（即樣品大小）無需太多；反之若取樣單位間之變異顯著，則表示試區內取樣單位間之差異很大，在這種試區內取樣，取樣單位之數目即需較多，並逢機的分布於整個試區，如此所取出之樣品才能代表整個試區。由一期作及二期作各性狀變方分析結果（表1.）可明顯看出雖然各性狀取樣單位內之變異（σ_W^2）較取樣單位間之變異（σ_A^2）爲大，但取樣單位間之差異仍達極顯著之水準。一、二期作各性狀取樣單位間之差異達極顯著之結果明顯表示試區內取樣之重要性。在田間試驗中，試區爲吾人施以處理（treatment）之最小單位，通常亦爲試驗記錄的最基本單位，因此若無法利用整個試區之材料而必須加以取樣時應注意防止取樣誤差（sampling error）之被導入試驗記錄中，不當的試區內取樣對試驗結果的正確性有很大的影響。一、二期作取樣單位間之差異極顯著亦提醒吾人在試區內取樣最好採用逢機取樣（random sampling）以減少取樣誤差。

表1. 取樣單位間與取樣單位內變異程度之比較

Table 1. Comparison of variability among and within the sampling units

Character	First crop				Second crop			
	Mean	F-value	σ_A^2(%)[a]	σ_W^2(%)[b]	Mean	F-value	σ_A^2(%)[a]	σ_W^2(%)[b]
Plant ht. (cm)	98.53	8.35**	44.9	55.1	104.72	4.20**	26.2	73.8
Panicle wt./plant (g)	33.60	2.26**	12.3	87.7	27.13	1.75**	7.7	92.3
No. of panicles/plant	16.52	3.35**	20.7	79.3	12.76	1.28*	3.0	97.0
Mean panicle length/plant (cm)	19.54	3.67**	23.3	76.7	20.09	2.09**	11.0	89.0
Wt. of filled grains/plant (g)	30.98	2.36**	13.1	86.9	24.39	1.91**	9.2	90.8
Total wt. of grains/plant (g)	32.12	2.27**	12.4	87.6	25.88	1.79**	8.1	91.9
No. of filled grains/plant	1,278.76	2.53**	14.5	85.5	1,038.81	1.94**	9.5	90.5
No of unfilled grains/plant	257.35	9.00**	47.0	53.0	345.28	2.69**	15.8	84.2
Mean no. of spikelets/plant	95.50	5.76**	34.6	65.4	109.13	3.14**	19.2	80.8
% of filled grains	83.43	11.14**	53.0	47.0	75.03	6.02**	35.8	64.2
1000-grain wt. (g)	24.25	3.44**	21.3	78.7	23.38	2.55**	14.5	85.5
Wt. of filled grains/panicle wt. (%)	73.88	7.05**	40.2	59.8	71.44	8.03**	43.8	56.2

*, **Significant at 5% and 1% levels, respectively.
a. Percent of variation among the sampling units.
b. Percent of variation within the sampling units.

(二) 取樣單位大小之影響

爲研究取樣單位大小對各性狀變異性之影響，分別以單株（1株×1株），相鄰二株（1株×2株），相鄰三株（1株×3株），相鄰四株（2株×2株），相鄰六株（2株×3株）及相鄰九株（3株×3株）爲取樣單位，計算各性狀在不同大小取樣單位下之變異係數值（表2.）。由表中可看出不論一、二期作，以單株爲取樣單位，變異係數均爲最高，但隨取樣單位之增大，變異係數即隨之減小。各性狀變異係數隨著取樣單位增大而減少之速率不盡一致，穗重，穗數，實粒重，實粒數，每穗穎花數等性狀，其變異係數減小之速率較快；反之株高，結實率，穗長等性狀，其變異係數減小之速率較慢，且不甚明顯。表2亦可看出變異性較大的性狀其變異係數減小的速率較快，變異性較小的性狀其變異係數減小的速率較慢。由一、二期作各性狀之變異係數值可發現凡與適應性（fittness）或繁衍後代有關之性狀如穗數，實粒重，每穗穎花數等均具有較大之變異性，而與適應性較無關之性狀，如株高，結實率，穗長等則具較小之變異性（Flaconer, 1960）；或謂與生殖（reproductivity）有關之性狀，變異性較與生殖無關之性狀爲大，或許如此才可保障物種在環境劇變下得以不致滅絕。由表2中可知，雖然各性狀之變異性差異很大，但都有隨取樣單位之增大而逐漸降低之趨勢，大致言之，一期作時以相鄰四株（2株×2株）爲取樣單位似乎在經濟上及準確程度上皆能兼顧。雖然以相鄰四株爲取樣單位，但對每一性狀却無需四株皆測量，變異性較大之穗數，穗重、實粒數、實粒重，每穗穎花數等可測量四株然後平均之，變異性較小之株高、結實率、穗長等則在取樣單位內逢機選取一或二株測量即可。二期作因單株取樣之變異性較一期作爲大，故最好以相鄰四株（2株×2株）或相鄰六株（2株×3株）爲取樣單位，以提高準確程度。如前所述，對變異性較大之性狀可測量取樣單位內之所有植株，對變異性較小之性狀則測量取樣單位內之一部分植株即可。

表2. 不同大小取樣單位下之變異係數值（%）

Table 2. Coefficients of variation (%) under different size of sampling unit

Character	First crop						Second crop					
	1×1[a]	1×2	1×3	2×2	2×3	3×3	1×1	1×2	1×3	2×2	2×3	3×3
Plant ht. (cm)	3.51	3.12	3.19	2.99	2.89	2.80	4.75	3.74	3.37	3.18	2.73	2.58
Panicle wt./plant (g)	24.19	17.41	14.60	11.91	11.09	11.15	29.72	24.50	19.92	17.64	14.40	13.16
No. of panicles/plant	31.63	22.53	18.20	16.66	14.52	15.50	25.42	21.63	17.09	15.51	12.41	10.69
Mean panicle length/plant (cm)	4.10	3.50	3.14	3.05	2.58	2.44	5.61	4.04	3.28	3.16	2.52	2.26
Wt. of filled grains/plant (g)	24.69	17.90	14.83	12.19	11.54	11.63	31.84	25.99	21.03	18.68	15.29	14.09
Total wt. of grains/plant (g)	24.33	17.51	14.55	11.91	11.09	11.23	30.86	25.07	20.17	17.83	14.60	13.41
No. of filled grains/plant	23.65	17.32	14.42	12.27	11.67	11.85	30.36	24.71	19.81	17.89	14.96	13.65
No of unfilled grains/plant	52.39	42.96	41.71	39.10	37.94	38.86	41.72	31.98	27.00	25.05	21.57	20.52
Mean no. of spikelets/plant	19.04	14.40	13.94	13.30	11.51	12.21	14.60	10.59	9.29	8.99	7.72	7.32
% of filled grains	7.87	6.72	6.52	6.22	6.36	6.33	9.79	8.21	7.18	7.03	6.27	5.89
1000-grain wt. (g)	6.03	4.37	4.09	3.51	3.42	3.37	6.76	4.52	4.03	3.87	3.34	3.17
Wt. of filled grains/panicle wt. (%)	2.71	2.83	2.52	2.36	2.22	2.16	5.93	4.17	3.43	3.42	2.96	2.85

a. hill×hill.

(三) 樣品大小之影響

樣品大小（每試區中所欲選出之取樣單位數）直接影響到試驗結果之準確程度。故以相鄰四株（

2株×2株）爲一取樣單位，則各性狀樣品大小與準確程度之關係分一、二期作列於表3。由表中可明顯看出各性狀之準確程度皆隨樣品之增大而提高。雖然加大取樣單位及增加樣品大小皆有助於提高準確程度，但通常增加樣品大小較加大取樣單位來得有效，比較本文表2及表3亦可發現此種結果。

表3. 以2株×2株取樣時，不同樣品大小下樣品平均之變異係數值（%）

Table 3. Coefficient of variation (%) of sample mean for different sample sizes based on 2-hill×2-hill sampling unit

Character	First crop							Second crop						
	2[a]	3	4	5	6	7	8	2	3	4	5	6	7	8
Plant ht. (cm)	2.11	1.72	1.49	1.33	1.22	1.13	1.06	2.25	1.84	1.59	1.42	1.30	1.20	1.12
Panicle wt./plant (g)	8.41	6.87	5.95	5.32	4.86	4.50	4.21	12.47	10.18	8.82	7.89	7.20	6.67	6.23
No. of panicles/plant	11.79	9.63	8.34	7.46	6.81	6.30	5.90	10.96	8.95	7.75	6.93	6.33	5.86	5.48
Mean panicle length/plant (cm)	2.16	1.77	1.53	1.37	1.25	1.16	1.08	2.25	1.83	1.59	1.42	1.30	1.20	1.12
Wt. of filled grains/plant (g)	8.62	7.04	6.10	5.45	4.98	4.61	4.31	13.20	10.78	9.34	8.33	7.62	7.06	6.60
Total wt. of grains/plant (g)	8.42	6.87	5.95	5.32	4.86	4.50	4.21	12.60	10.29	8.91	7.97	7.27	6.73	6.30
No. of filled grains/plant	8.68	7.09	6.14	5.49	5.01	4.64	4.34	12.65	10.33	8.95	8.00	7.31	6.76	6.33
No of unfilled grains/plant	27.61	22.55	19.52	17.46	15.94	14.76	13.81	20.33	16.60	14.33	12.86	11.74	10.87	10.16
Mean no. of spikelets/plant	9.41	7.68	6.65	5.95	5.43	5.03	4.70	6.36	5.19	4.50	4.02	3.67	3.40	3.18
% of filled grains	4.40	3.59	3.11	2.78	2.54	2.33	2.20	4.97	4.06	3.51	3.14	2.87	2.65	2.48
1000-grain wt. (g)	2.47	2.02	1.75	1.56	1.43	1.32	1.24	2.73	2.23	1.93	1.73	1.57	1.46	1.36
Wt. of filled grains/panicle wt. (%)	1.67	1.37	1.18	1.06	0.97	0.89	0.84	2.42	1.98	1.71	1.53	1.40	1.29	1.21

a. No. of 2-hill×2-hill sampling units per plot.

對一期作而言，除產量外，以相鄰四株爲一取樣單位，若在每試區內逢機選取3個取樣單位（共12株），則對各性狀之準確程度已大體都能兼顧。穗數，每穗穎花數，結實率，千粒重等產量構成要素之變異已相當小（變異係數值在2.02%至9.63%之間）。二期作時，設仍以相鄰四株爲取樣單位，若在每試區中逢機選取4個取樣單位（共16株）則各性狀之準確程度即大致與一期作相似，對較重要之4個產量構成要素，其變異係數值在1.93%至7.75%之間，可謂相當準確。

綜論一、二期作，水稻田間試驗之試區取樣，若以相鄰四株（2株×2株）爲一取樣單位，而在每一試區內逢機選取3到4個取樣單位組成一樣品作爲試區估值，則對各重要農藝性狀之準確程度大體已都能兼顧。

（四）實粒重與其他性狀之相關

各性狀間之相關列於表4，其中上三角（upper triangle）部分爲一期作，下三角（lower triangle）部分爲二期作。爲避免混合作用（blending effect），故所有相關皆以單株觀測值計算，而不以各種取樣單位下之平均值計算。由表中發現實粒重與穗重、穗數及實粒數之相關極高（0.74到0.99），與所謂產量構成要素如每穗穎花數，結實率，及千粒重等「導出性狀」（derived character）之相關反而很小（-0.04到0.38），且一、二期作均有此現象。因本研究所採之樣品甚大，故表4中實粒重與前述導出性狀之相關，有些在統計上亦達顯著水準，但實際應用上却無甚大價值。理論上實粒重應由穗數，每穗穎花數，結實率及千粒重等4個要素（components）所完全決定，但實際上此4個構成要素中除穗數外，其餘3個性狀皆非直接測量而來，如每穗穎花數是以總粒數（包括實粒

與空粒）除以穗數而得；結實率是以實粒數除以總粒數而得；千粒重是以實粒重除以實粒數而得，因此將其稱爲「導出性狀」。由於4個產量構成要素皆互相關連而非彼此獨立測量而來，故雖然實粒重與穗數、實粒數、總粒數等性狀之相關很高，但不一定與前述導出性狀也有很高之相關，甚至相關很低。因此作選拔（selection）或作產預測（prediction）時應以4個要素之乘積作指標，而不能以個別要素爲對象。

由表4中可發現不論在第一、二期作，實粒重與穗數之相關均極高，分別爲0.74與0.81，此點或許可利用於單位面積之產量預測。因與實粒重有高相關之穗重、穗數及實粒數中只有穗數是可以早期決定且大量測量之性狀。

表4 實粒重與其它性狀之相關（上三角部分爲一期作，下三角部分爲二期作）

Table 4. Correlation coefficients among weight of filled grains and other characters in the first (upper trangle) and the second (lower triangle) crop

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}
X_1[a]		0.393	0.229	0.281	0.389	0.399	0.386	0.227	0.200	−0.030	0.049	0.077
X_2	0.503[b]		0.763	0.207	0.992	0.997	0.969	0.267	−0.032	0.221	0.155	0.181
X_3	0.350	0.837		−0.189	0.739	0.761	0.721	0.479	−0.534	−0.106	0.106	−0.016
X_4	0.243	0.205	−0.178		0.212	0.205	0.211	−0.050	0.516	0.173	0.053	0.125
X_5	0.508	0.994	0.810	0.215		0.997	0.958	0.182	−0.038	0.304	0.190	0.296
X_6	0.509	0.997	0.833	0.207	0.998		0.971	0.256	−0.030	0.234	0.160	0.238
X_7	0.487	0.983	0.831	0.182	0.985	0 986		0.259	0.063	0.242	−0.057	0.225
X_8	0.260	0.523	0.715	−0.038	0.463	0.513	0.503		0.046	−0.843	−0.279	−0.588
X_9	0.309	0.299	−0.148	0.691	0.311	0.304	0.328	0.106		−0.018	−0.384	−0.022
X_{10}	0.137	0.267	−0.069	0.220	0.332	0.280	0.294	−0.634	0.179		0.274	0.745
X_{11}	0.272	0.352	0.154	0.273	0.381	0.362	0.225	−0.066	0.028	0.321		0.313
X_{12}	0.207	0.270	0.066	0.185	0.368	0.328	0.318	−0.298	0.189	0.660	0.448	

[a] X_1=Plant ht. (cm)
X_2=Panicle wt'/plant (g)
X_3=No. of panicles/plant
X_4=Mean panicle length/plant (cm)
X_5=Wt. of filled grains/plant (g)
X_6=Total wt. of grains/plant (g)
X_7 =No. of filled grains/plant
X_8 =No. of unfilled grains/plant
X_9 =Mean no. of spikelets/plant
X_{10}=% of filled grains
X_{11}=1000-grain wt. (g)
X_{12}=Wt. of filled grains/panicle wt. (%)

b. 5% and 1% significant correlation coefficients are 0.198 and 0.261 respectively.

結　　論

取樣方法的適當與否直接影響到試驗結果的準確性。一般田間試驗皆是在有限的人力、經費與時間下進行，如何在這些限制條件下經濟有效的獲得有用的資料，端賴良好的試驗設計與取樣方法。

本文探討在不同期作下，水稻重要農藝性狀之適當取樣單位及樣品大小。結果發現除產量外，相鄰四株（2株×2株）之取樣單位可應用於一期作，而相鄰四株（2株×2株）或相鄰六株（2株×3株）之取樣單位可應用於二期作。至於樣品大小在一期作時每試區內取3個取樣單位已足夠，二期作時每試區取4個取樣單位較準確。由本研究之結果可發現，由於不同農藝性狀各有其變異性（variability）故對某一性狀最合適之取樣單位與樣品大小往往並不適用於其它性狀，而實際操作上又不便給予每一性狀一種取樣單位及樣品大小，因此前述所建議之取樣單位及樣品大小可視爲權衡各性狀後的一種折衷；對變異性較大或較重要之性狀，則取樣單位內之每一植株均予測量，對變異性較小的性狀則僅測量取樣單位內之一或二株即可。

田間試驗中，雖然試驗者皆力求使試區內之植株表現儘可能相同，但由本研究結果可知試區內之植株仍有一定之變異性，此種變異性之來源除植株本身之固有變異（inherent variability）外，尙有土壤變異，邊際影響（border effect），缺株影響（missing plant effect），肥料施用的不均勻，病蟲害及其它不當田間管理工作所引起的偏性因素，試驗者除應盡力控制上述偏性因素外，尙應盡可能在試區內以逢機方法取樣，以使可能導入試驗結果之偏性因素能有機會互相抵消。

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Studies on Sampling Method of Rice Agronomic Characters.

I. Comparison between Crops[1]

C. Liu, H. Ho and S. H. Tsao[2]

Summary

This paper investigated the appropriate sampling unit and sample size, under plot sampling, for various agronomic characters of rice. Using Tainung 67 as experimental variety, 12 agronomic characters including grain weight and yield components were measured for the second crop of 1981 and for the first crop of 1982. Analyses performed were (1) variability comparison among and within the sampling units, (2) effects of the size of sampling unit, (3) effects of the smple size and (4) the relationship between yield components and the weight of filled grains.

Data revealed that variation within individual sampling units was always larger than that among different sampling units. Furthermore, the difference between sampling units ware also highly significant for both crops and all measured characters, indicating that some sort of variation existed among plants within the same plot. Excepting yield, 4 adjacent hills (2-hill×2-hill) should be counted as a sampling unit for the first crop, and either 4 adjacent hills (2-hill×2-hill) or 6 adjacent hills (2-hill×3-hill) should be used for the second crop. A sample size of 3 sampling units for the first corp and 4 sampling units for the second crop are considered appropriate. The selection of sampling units should be random whenever possible in order to cancel out any potential bias associated with the experimental results.

The weight of filled grains correlated closely with the number of panicles per hill (0.74 for the first and 0.81 for the second crop). However, there was very little correlation with such "derived" yield components as the number of spikelets per panicle, % of filled grains, and the 1000-grain weight. Therefore, the product total of the four yield components, rather than any derived one should be used as an index in making selections or predicting yield.

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2. Senior Statistician, Assistant Statistian and Assistant, respectively, of the Department of Agronomy, TARI, Wufeng, Taichung Hsien, Taiwan 431, ROC.

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促進蓮霧提早開花調節產期之研究[1]

Ⅱ. 化學藥劑及耕作處理對蓮霧催花效果之研究

王 德 男[2]

摘要：本試驗探討於夏季期間以耕作處理和生長抑制劑噴用對於促使蓮霧由營養生長轉入生殖生長之穩定性，以應用於蓮霧之促成栽培，結果顯示，耕作處理對於蓮霧促進開花之效果比藥劑處理為佳。以斷根和浸水處理併用之早花率達最高。生長抑制劑以 Ethrel 和 C. C. C. 兩種藥劑最為有效。

在蓮霧促成栽培上，夏季期間以斷根、浸水處理再噴以生長抑制劑可使蓮霧比一般栽培之花期（3－5月）提早半年，生產期也因而提早半年，可於國曆新年前採收。同時如有適當之施肥管理，在一年內可收穫達六次。

本省熱帶果樹栽培之產期調節，除鳳梨用電石處理[7,9]，香蕉、木瓜等短期果樹以栽植期[9]及番石榴、番荔枝以修剪[9]外，其它熱帶果樹皆未能有技術突破。因此產期集中和盛產滯銷之事時有發生。如何促進提早開不時花（off-season flower)以調節產期已成為多種熱帶果樹栽培上最重要之一環。

化學藥劑處理為當今調節植物花期最盛行之方法，利用化學藥劑來調節花期已有許多成功的報告：如鳳梨用電石[6,7,8,9]、Naphthalene Acetic Acid（NAA）2, 4-D、Etherel[6,8,9]處理；檬果用 Ethrel[4,12,13,17,32,35]、Alar[4,24,25]、Chlorocholine Chloride〔Cycocel（C. C. C.）〕[24,25]、KNO_3[17,32]、Agriblum[17]處理均可獲得若干成效，此外亦有利用 GA_3 延遲花期[14,19]以調節產期；上述化學藥劑中僅 NAA 被應用於提早蓮霧花期[1]，其餘藥劑迄今國內外尚未見有應用於蓮霧之報告。耕作處理亦為當今調節作物花期常用之方法如番石榴、番荔枝利用修剪[9]；荔枝利用環狀剝皮（Girdling)[27,28]、斷根[9]、乾旱[9]；檬果之用剪穗[4]、環刻亦可成功地調節上述果樹之花期，但對蓮霧之效果如何亦不詳。

蓮霧在南部地區由於夏季高溫多雨，土壤裡如有充分之養分供給時，新梢繼續生長，植株保持養營生長。通常經秋季乾旱期間，新梢生長緩慢；枝葉轉為成熟而漸進入生殖生長，翌年2－3月間開花，5－6月間果實收穫。

近年來於10月中旬（雙十節前後一週）如植體枝葉成長成熟，已進入生殖生長時農家常以各種催花劑噴佈植體，可促進其開花，然而在噴佈藥劑時，常由於天候等因素無法控制使其有成熟之狀態或進入完全生殖生長狀態，因此，噴佈催花劑失敗者到處發生。本試驗為求此植體能在此時間提早完成營養生長，以耕作處理如斷根、浸水和生長抑制劑噴佈，促使旺盛營養生長得以控制，使樹體在9－

1.臺灣省農業試驗所　研究報告第1089號。本研究係中央加强農村建設補助計畫〔70—農建—5.1—產—46（1）〕及〔71—農建—2.1—產—53〕之一部分，並承國科會研究補助。試驗期間承總所萬所長雄及農發會李技正金龍博士鼓勵與支持，文成復承陳主任敏祥及沈分所長再發悉心斧正，謹致謝忱。
2.本所鳳山熱帶園藝試驗分所助理研究員。臺灣省 高雄縣 鳳山市。

10月間完成生殖生長爲目標，再以催花劑處理，建立蓮霧促成栽培之模式。

材 料 與 方 法

(一) 藥劑處理對催花效果之影響：

利用本分所A試區面積0.7公頃(民國67年6月底種植3年生)，粉紅色南洋種蓮霧爲材料。以下列藥劑噴佈：(A) NAA 100 ppm (美國 millmaster 98% 粉劑)，(B) Agribrum 100 倍 (菲律賓 A. G. P. 出品，液劑)，(C) Alar 1000 倍 (新加坡 Uniroyal 85% 粉劑)，(D) Amex 100 倍 (美國 Amchem 36% 液劑)，(E) Ethrel 2000 倍 (美國 Amchem 39.5% 液劑)，(F) GA_3 1000 倍 (英國 ICI 10% 片劑)，(G) KNO_3 10%、(H) C. C. C. 200 倍 (美國 Sigma)、(I) $KH_2PO_4+Mg_2\ SO_4$+Borax 各 400 倍，(J) MH-30 100 倍 (美國 Uniroyal 30% 液劑)，(K) C. K 不處理等 11 處理。噴佈時間於9月1日、9月15日及9月30日將進入乾季時，計噴3次。處理後各試區於10月13日皆同樣以50%速滅松 (Sumithion) 乳劑 500 倍加日本旭化學工業株式會社1.95%愛多收 (Atonik) 溶液 3000 倍行催花處理。當年12月14日和12月 29日分別調查其開花率，開花率以每棵在東、西、南、北不同方向之中央部份一公尺見方內有花果之枝梢百分率之平均值計算。

(二) 耕作處理對催花效果之影響：

利用本分所 B 試區面積 0.8 公頃 (民國66年10月定植4年生)，粉紅色南洋種蓮霧爲材料。於8月29日—30日行下列處理：(A) 浸水 (圖1)，(B) 斷根：離樹幹 60 cm 處挖深 30 cm，寬 30 cm (圖2)，(C) 乾旱：任由自然乾旱而不行人工灌水，(D) 環狀剝皮：於主枝基部行 1—3 cm 寬之環剝 (圖3)，(E) 修剪：將直立枝、徒長枝、向上枝、密生枝及枯枝剪除。(F) 不修剪 (CK) 等6種處理後各試區於10月14日皆同樣以50%速滅松 (Sumithion) 乳劑500倍加1.95%愛多收 (Atonik) 細胞賦活劑1000倍加美國 Millmaster 出品 98% NAA 100 ppm 行催花處理。自11月1日起約每隔半個月調查各處理開花率計7次。以資比較催花處理前之各項耕作處理等之效果。

(三) 不同耕作處理後繼以不同化學藥劑噴佈對催花效果之影響：

以本分所A試區 (民國67年4月定植4年生) 粉紅色南洋種蓮霧爲材料。耕作處理分斷根、浸水、斷根＋浸水及不斷根不浸水等4種處理；化學藥劑處理分 Ethrel 2000 倍，Cycocel 200 倍及不行藥劑處理等3種處理，即4種耕作處用×3種藥劑處理共計12種處理，每處理6株共計72株。耕作處理於植體生長旺盛期之7—8月間行之，浸水處理於7月20日起浸40天其間放水7天；斷根處理於8月10日行之；斷根＋浸水區分別於8月10日和8月13日行之。化學藥劑 Ethrel 2000 倍或 Cycocel 200 倍分別於8月13日、9月8日及9月29日共3次，復於10月7日再全部以50%速滅松乳劑 400 倍加愛多收3000倍行催花處理。從70年10月14日至71年1月6日止共調查其促成花果之枝條數及花果穗數5次。並於各期果實之盛收期70年11月16日、70年12月31日、71年2月12日、71年3月2日、71年5月13日及71年7月23日各採收20個成熟度約略一致之果實調查其果實、果高、果徑及糖度，並估算每株每期之收穫量。

試驗期間之施肥分別於70年10月12日每株施1：1：2三要素混合肥料2.0公斤、71年12月30日施1：2：2.5三要素混合肥料1.6公斤、71年2月25日及5月5日再各施1：1.5：2.5之三要素混合肥料各1.3公斤，計施4次，每株共施6.2公斤的三要素化學肥料。

試 驗 結 果

(一) 藥劑處理對蓮霧催花效果之影響：

10種不同藥劑處理中，以益收 (Ethrel) 2000 倍對蓮霧催花效果最大，平均早花率 15.2%，尤以連續處理3次者—25.7%爲最高；C. C. C. 200 倍次之 (11.0%)；NAA 100倍處理一次者雖亦

圖1. 蓮霧浸水處理情形

Fig. 1. Waterlogging treatment was made on wax-apple plant.

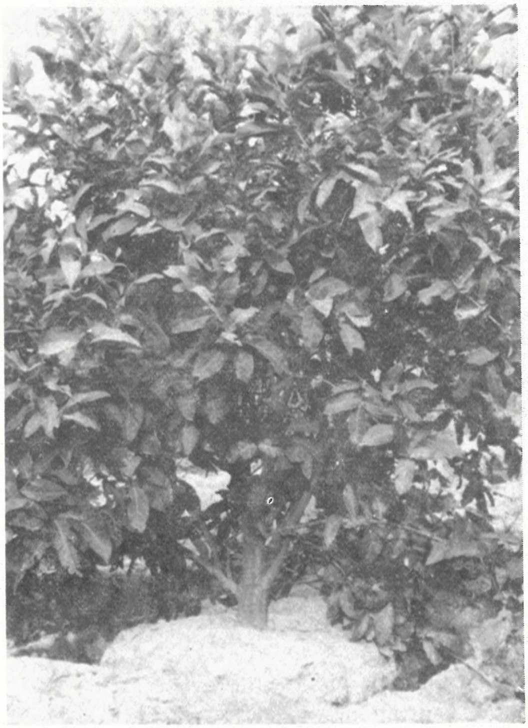

圖2. 斷根處理情形

Fig. 2. Wax-apple plant was treated by root-pruning.

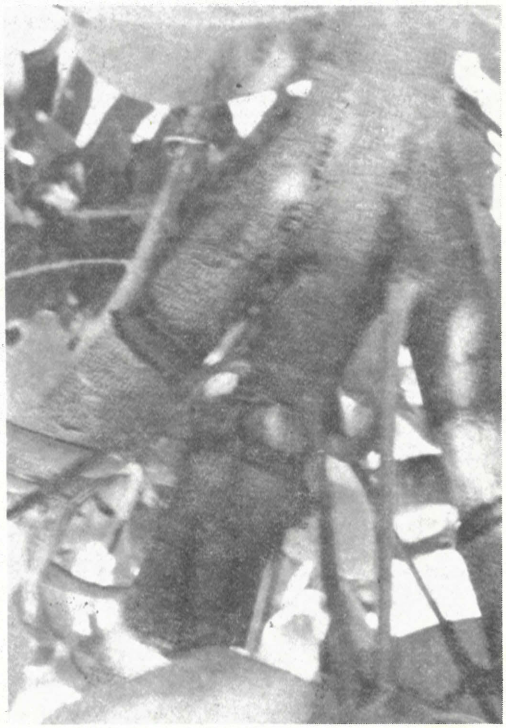

圖3. 蓮霧枝幹環狀剝皮處理情形

Fig. 3. Girdling trunks was made on wax apple.

有效（7.6%），但若處理二次以上反而對催花效果有不利之影響（圖 4），與前年預備試驗結果相同。

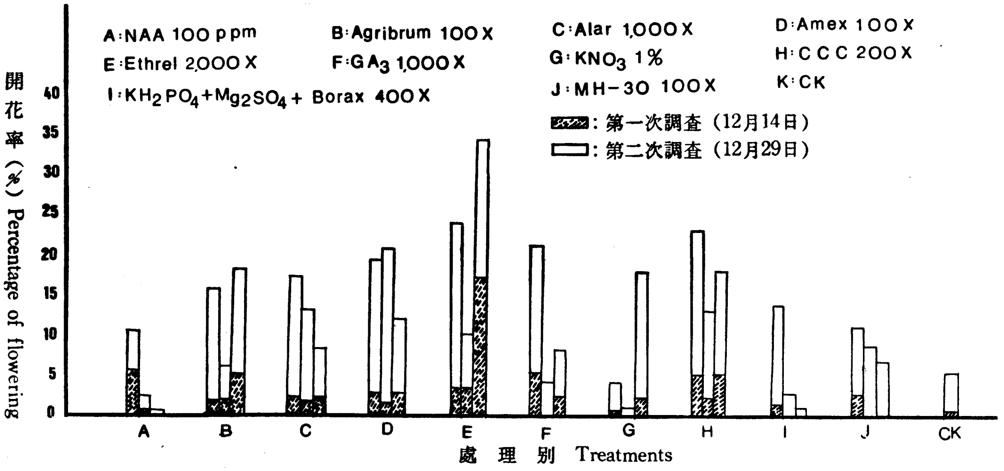

圖4. 不同藥劑處理間之開花情形

註：在不同處理中，由左至右依次爲三處理 1、2、3 次者。

Fig. 4. Percentage of flowering among treatments.

（二）耕作處理對蓮霧催花效果之影響：

六種不同耕作處理之催花效果以浸水處理和斷根處理開花最早。於11月 1 日之開花率，浸水處理區爲0.7%，斷根處理爲0.2%，而其他處理尚未有開花現象。比其他處理提早二週開花，但可能因浸水及斷根二處理對勢損傷較大，致後期開花率反而比其他處理低（圖 5）。

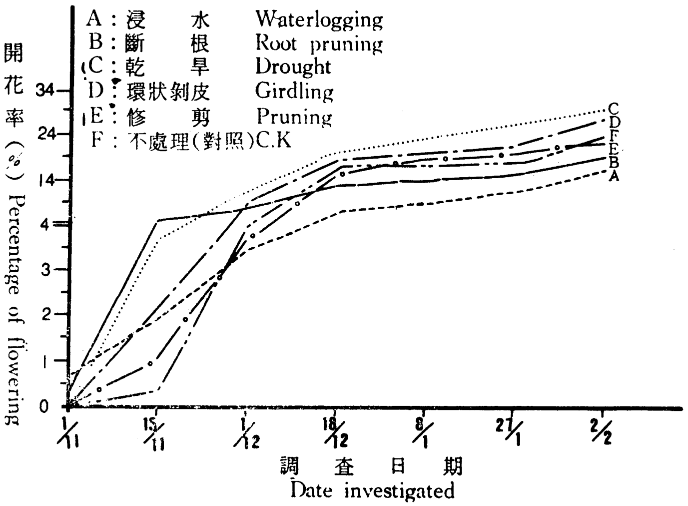

圖5. 不同耕作處理間之開花率。

Fig. 5. The percentage of flowering among cultural treatments.

（三）不同耕作處理後繼以不同化學藥劑噴佈對蓮霧之催花效果：

1. 耕作處理與化學藥劑聯合處理對蓮霧開花之影響：其結果整理如表 1。

表1. 不同耕作處理後續以不同化學藥劑處理對催花之效果

Table 1. Effects of cultural and chemical treatments on flower forcing of Wax-apple.

處理別 Treatments* \ 調查日期 Dates investigated \ 項目 Items	花果穗數（穗／株） Panicles per plant					有花果之枝條數（枝／株） Bearing branches per plant				
	10.14. (1981)	11.10. (1981)	12.2. (1981)	12.16. (1981)	1.6. (1982)	10.14. (1981)	11.10. (1981)	12.2. (1981)	12.16. (1981)	1.6. (1982)
1. 斷根（root pruning）＋浸水（Waterlogging）＋Ethrel 2000 倍	39.0	281.8	505.8	694.8	791.3	4.3	41.7	100.3	103.0	115.8
2. 斷根（root pruning）＋浸水（Waterlogging）＋C. C. C. 2000 倍	37.3	203.3	295.3	298.3	320.5	6.0	50.7	62.8	63.8	75.0
3. 斷根（root pruning）＋Ethrel 200 倍	17.8	55.2	94.8	115.0	194.7	2.7	12.6	22.0	27.7	39.1
4. 斷根（root pruning）＋C. C. C. 200 倍	2.5	61.8	117.5	121.8	135.7	2.5	16.2	26.8	28.0	30.0
5. 浸水（waterlogging）＋Ethrel 2000 倍	7.0	116.0	250.8	275.6	508.0	1.8	20.2	45.8	48.5	71.3
6. 浸水（waterlogging）＋C. C. C. 200 倍	5.1	234.3	266.8	271.2	363.8	1.5	54.0	64.5	65.8	75.5
7. 斷根（root pruning）＋浸水（waterlogging）	34.3	216.6	261.6	284.3	336.0	7.3	35.0	49.6	59.3	70.6
8. Ethrel 2000 倍	3.0	28.3	57.8	60.7	124.3	3.0	9.2	15.2	19.7	32.7
9. C. C. C. 200 倍	1.5	77.5	79.8	114.1	119.2	1.5	19.7	21.9	21.1	27.5
10 浸水（waterlogging）	20.3	185.6	265.6	274.3	354.3	3.0	38.6	57.6	59.6	70.0
11. 斷根（root pruning）	15.3	102.0	218.0	220.0	256.3	4.3	19.3	38.0	39.0	45.0
12. 對照（CK）*	0	1.6	10.0	20.6	59.3	0	0.6	4.0	7.6	17.3

* 耕作處理：浸水—70年7月20日起40天，中間放水7天。斷根—70年8月10日

Cultural practices: Flooding 40 days from 20th, July with 7 days interruption (draniage). Root pruning-on 10th, August, 1981.

化學藥劑：70年8月13日、9月8日、9月29日計三次。

Chemical sprayings: Three times each on 13th, August, 8th, September and 29th, September, 1981.

**對照（CK）未行斷根、浸水及 Ethrel 或 C. C. C. 處理，但與其他處理皆同樣於70年10月7日行催花處理。

CK: Untreated plants. All the plants have identical treatment on 7th, October, 1981 for flower forcing.

由上表得知單獨處理間以浸水處理最好，不但早花數最多各期花果穗數亦最高，其次爲斷根處理，顯示耕作處理對促進蓮霧提早開花之催花效果比藥劑處理爲佳。二者聯合處理間以同時行斷根及浸水處理之早花數最高（34.3穗／株），其次爲斷根＋Ethrel（17.8穗／株）。三者聯合處理—斷根＋浸水再噴以化學藥劑 Ethrel 或 C. C. C. 之效果最佳，分別高達3.9.0穗／株及37.3穗／株。

2.促成栽培對蓮霧收穫次數及產量之影響：

表2. 蓮霧促成栽培處理對收穫次數及產量之效果

Table 2. Effects of different forcing treatments on harvesting times and yield in Wax-apple.

處理別 Treatments * \ 採收期別 Harvesting time / 盛收期 peak harvesting day	第一收 1st crop	第二收 2nd crop	第三收 3rd crop	第四收 4th crop	第五收 5th crop	第六收 6th crop	合計 (公斤/株) Total (kg/plant)
	11.16. 1981	12.31. 1981	2.12. 1982	3.12. 1982	5.13. 1982	7.23. 1982	
斷根 (root pruning) + 浸水 (waterlogging) + 化學藥劑處理 (Chemicals treatment)	3.5**	8.0	10.8	15.4	20.3	18.6	76.6 (153.2)
對照區 (CK)	—	—	—	8.8	21.5	19.7	50.0 (1000)

* 斷根—70年8月10日，浸水—70年8月13日，化學藥劑—Ethrel 70年8月13日、9月8日、9月29日計三次。

Root pruning-10th, August, Waterlogging-13th, August, 1981.

Chemical-13th, August, 8th, September and 29th, Sepetmber, 1981.

**產量以各該採收期之盛收日可採果實重量估算。

Yield was estimated by number of full grown fruits on peak harvesting day.

在採收方面，蓮霧催花處理前若先行斷根、浸水及化學藥劑 Ethrel 或 C. C. C. 行促成栽培處理可提早採收，在11月6日行第1次收穫，12月31日行第2次收穫、次年2月12日行第3次收穫，而對照在此期間皆未能有收穫。收穫次數由對照（於10月7日行催花處理）之3次增加到6次，總產量估計約增加53.2%。

3.促成栽培對蓮霧品質之影響：

表3. 蓮霧促成栽培處理對品質之影響

Table 3. Infuences of forcing treatments on fruit quality of Wa-apple.

處理別 Treatments	採收期別 Harvesting time	盛收期 Peak harvesting day	果重 Weight (g)	果高 Height (cm)	果徑 Diameter (cm)	糖度 Brix
斷根 (root pruning) + 浸水 (Waterlogging) + 化學藥劑處理 (Chemicals treatment)	第一次1st crop	11.16.1981	62.8	5.0	5.4	9.6
	第二次2nd crop	12.31.1981	55.7	4.3	5.1	7.8
	第三次3rd crop	2.12.1982	69.3	5.4	6.0	6.1
	第四次4th crop	3. 2.1982	70.9	5.5	5.6	6.2
	第五次5th crop	5.13.1982	68.1	5.7	5.7	6.1
	第六次6th crop	7.23.1982	61.3	5.1	5.5	9.8
	平 均Mean		64.7	5.2	5.6	7.6
對照區 (CK)	第一次1st crop	3. 2.1982	64.5	5.2	5.8	6.4
	第二次2nd crop	5.13.1982	67.0	5.7	5.7	5.7
	第三次3rd crop	7.23.1982	62.5	5.1	5.5	9.3
	平 均Mean		64.7	5.3	5.7	7.1

* 處理日期同表2 See Table 2.

利用斷根、浸水及化學醫劑聯合處理以促成栽培蓮霧，雖然由收穫期增加，但果重及果形大小却不因收穫期之增加而降低，最重要的果實之糖度却以促成栽培的第1和第2次收穫最高，此時生產期間適爲國曆過年前可爲珍品。

討　論

斷根、浸水、環狀剝皮、乾旱等耕作處理雖均爲調節果樹花期常用方法。但並非每一種方法對每一種果樹均可適用，而與果樹之開花結果習性及開花結果生理之不同而異，如番石榴、番荔枝利用修剪 [9]；荔枝利用環狀剝皮 [27,28]、斷根、乾旱 [9]；檬果利用剪穗 [4]、環刻 [29] 均可成功調節花期。本研究發現僅斷根及浸水對促進蓮霧提早開花之催花效果有效，環狀剝皮及乾旱處理效果不佳。據 Murneek [25] 報告，環狀剝皮可切斷韌皮部，使碳水化合物大量蓄積於枝葉而提高碳氮比(C/N Ratio)，可提早開花。但該項方法應用於蓮霧上，由於蓮霧樹性生長旺盛、癒傷組織（Callus）形成快速，環剝1公分者經2週後即全癒合，致效果不彰。至於乾旱處理效果不顯，蓋因於8月底行乾旱處理時仍爲雨季，本擬由乾旱以抑制其旺盛之營養生長，乃由於試驗期間常雨，園地無法充分乾旱之故，該項處理，也就失去其效果性。

植物根爲 Cytokinins 生成之主要器官 [5,24,30]，斷根可抑制番茄生長，加速葉片老化變黃 [5]；浸水（Flooding or waterlogging）可導致土壤一系列之化學及生物變化如使酸性土壤之 pH 提高，而鹼性土壤之 pH 值降低及土壤中氧濃度降低，二氧化碳濃度增高 [23,30]，而造成根部缺氧（O_2 deficit）[23,30]；另可降低電位差(Redox potenical）使硝酸根（NO_3^-）還原成氣態氮（N_2）（脫氮而消失）；硫酸根 $SO_4^{=}$ 還原成硫化氫（H_2S）；二氧化碳（CO_2）還原成甲烷（CH_4），此種 CH_4、H_2S 及其他有毒的還原物質，常可使根部腐敗阻礙氮、磷、鉀、鈣、鎂、錳、鐵、錳、鋅硼氯等礦物元素之吸收 [3]；另可使三價鐵，四價錳（Fe^{3+}、Mn^{4+}）還原成二價鐵錳離子（Fe^{2+}、Mn^{2+}）而溶解向下移動溶脫；蓄積於犁底層而造成毒害 [23,30] 及耕犁層缺鐵而產生葉片黃化現象 [23,30]；並使 Gibberellin 及 Cytokinin 含量急速降低 [22,30]；Abscisic acid（ABA）及 Ethylene 含量顯著增加 [22,30]，而乙烯有促進葉片老化，增加酵素之活性，促進開花之功效 [5,10]。蓮霧園經斷根、浸水處理後植株體內各種內生生長素 GA、Cytokinin、ABA、Ethylene 之含量變化如何，爲今後研究生理方向值得研究探討的問題。斷根、浸水處理後可顯著抑制抽梢生長，使葉片老化變黃而達促進提早開花 [5,22,23]。蓮霧栽培上，夏季生長旺盛期行浸水及斷根處理後，生長轉爲衰弱，開花結果期因而提早，而達到蓮霧促成栽培之目的。

化學藥劑處理也爲調節植物花期之一種方法。本研究從 10 種不同化學藥劑中發現僅 Ethrel 及 C. C. C. 處理對促進蓮霧提早開花之催花效果較爲顯著。Ethrel 使用後所產生之 Ethylene，其功效已如前述 [5,10]，至於 C. C. C. 對植物體之作用方式（Mode of action）如何？學者間之主張不一，Kuraishi 和 Muir 二氏 [21] 認爲 C. C. C. 是一種 Anti-Auxin 之方式；Cathy 氏 [11] 則認爲 C. C. C. 能改變植物體內代謝作用，能使 Gibberellin 的合成減少、因而可以影響植物之生長和發育，是一種 anti-metabolite 之作用。其後學者 Harada [18] 證實了 C. C. C. 的作用方式抑制植物體內 Gibberellin 之生合成（biosynthesis), Dannis et al [16] 認爲 C. C. C. 之作用 Site 爲：

Mevalonic acid→trans-Geranylgeraniol—‖(C. C. C.)‖→（−）Kaurene→→→Gibberellic acid，因此 C. C. C. 能使植物矮化及影響其他之生理作用。在蓮霧上，C. C. C. 於以斷根浸水後噴用，可抑制其營養生長，並促進其加速轉入生殖生長，而達到蓮霧提早開花促成栽培的目的。

藥劑處理對促進蓮霧提早開花之催花效果，以 Ethrel 2000 倍較 Cycocel 200 倍爲佳，但對斷根＋浸水處理區可能因 Ethrel 之使用濃度過高致會造成葉片大量黃化落葉，影響果實發育大小及品質，今後宜再進一步探究最適當之使用濃度。

利用化學藥劑及耕作處理促進蓮霧提早開花常因使用濃度[1]、時間[2,3]、方法及氣候、土壤、品種、樹齡、樹勢及肥培管理之不同而效果不一，即使在同一天用同一種藥劑濃度分別施用於相鄰二園，可能一園非常成功而另一園則完全失敗；又即使同一園同一處理中，亦有些植株非常成功，而有些樹則不成功；顯示株間差異甚大，以致造成本研究中部分試驗不同處理間催花效果差異不顯著。

本研究經連續二年之試驗已初步探得促進蓮霧提早開花之有效藥劑及耕作處理方法，但催花處理之效果牽涉範圍甚廣，非一朝一夕可以完成，需進一步且多年之進行，才能獲致具體結論，故今後除應繼續進一步探究斷根、浸水之最適當程度、時期及化學藥劑 Ethrel、C. C. C. 之最適當濃度外，並應繼續探究氮肥對催花效果之影響，以澈底解決蓮霧催花效果之穩定性，俾可完全有效控制（提早）開花，調節產期，以穩定產銷。

Kraus 與 Kraybill[20] 以番茄為材料，將土壤之水分和氮素狀態以人為調節成種種程度，調查C/N 之關係對於生長與開花結果指出；水分、氮素之供給稍衰，而碳水化合物之生成豐富、蓄積於體內時、枝葉生長雖然稍為衰弱，但花芽之形成結果佳良。蓮霧由於夏季之高溫多雨，適於營養生長，如再有養分之供給時，新梢生長更旺盛，而難於轉入生殖生長。在此旺盛之生長條件，以斷根浸水等方式造成逆境（Stress），使其生長受到抑制而提早轉入生殖生長。同時藉催花劑之噴用可達到促成栽培之目的。另一方面，進入秋冬季節、由於氣溫之略為降低、有充足之陽光條件，雖然乾旱而能有適足灌溉與施肥，因此、可促進蓮霧陸續開花結果達6次之多，較不用生長抑制及耕作處理的催花（10月中旬）3次收穫多收3次，而與一般的自然栽培僅能於5－7月間的收1－2次多出4－5次。在品質方面，第1、2次收之糖度最高，果實色紅、淸脆而甜，可謂蓮霧之珍品。另外第6次收，糖度也高；此三回之高品質，推測可能前二次之結果數較少，樹體內有很高之碳水化合物蓄積，而最後一次為結果成熟期，沒有陸續之開花出現，有足够之碳水化合物供果實之發育所致。其餘各次果實收穫期內，皆在陸續開花之同時，因此品質似因而略為遜些。

蓮霧之促成栽培，由於9－10月間時有未能達到完全之生殖生長，以致促成生產未能穩定。本試驗針對此癥結，以浸水、斷根或以斷根＋浸水，再以生長抑制劑噴佈、使樹體提早完成生殖生長，然後以催花劑促使開花，而達到穩定的促成栽培技術。

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Flower Forcing in Wax-apple[1]

II. Effects of Cultural and Chemical Treatments on Flower Induction of Wax-apple.

by

Der-Nan Wang[2]

Summary

To industrialize the flower forcing treatment of wax-appple, the stability among cultural and chemical treatments in the summer time on the inductio n of flowering is investigated, the results indicate that cultural practices are superior to chemical sprayings--especially root pruning in combination with waterlogging. Ethrel and Cycocel are better flower induction reagents among chemicals used.

Accurate cultural practices plus chemical spraying makes wax-apple trees produce off-season fruits six months earlier (period of high economic value) than normal trees. Besides, six crops per year is possible under adequate management practices.

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2. Assistant Horticulturist, Fengshan City, Kaohsiung Hsien, Taiwan 830, ROC.

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光線、培養基、酸鹼度及溫度對 *Lepiota naucina* 菌絲生長之影響[1]

廖 英 明[2]

摘要：以馬鈴薯洋菜培養基 (potato dextrose agar) 培養 *Lepiota naucina* 菌絲時發現其在 8°C 以下或 36 °C 以上時無法生長，而最適合生長之溫度爲 24 °C。在連續光照或光照與黑暗互相交替下較連續黑暗不利於菌絲生長。若以液體培養，測定酸鹼度由4.6至 10.0 時對菌絲生長之影響發現酸鹼度在5.3至9.2時均適合其生長，而以 7.8爲最適合。菌種培養試驗時以麥粒爲材料最適合菌絲生長。在 9 種液體培養基中以下列培養基裝於 250 ml 之三角瓶中，容量爲 100ml 時可得到最高之菌絲乾重量，培養基含硝酸鈣、磷酸二氫鉀、麥芽抽出物、硫酸鎂、氯化鉀、磷酸鐵、麥芽糖及蛋白腖。碳氮比爲30時最適合菌絲之生長。

Lepiota naucina Fr. 爲一種生長於草地、放牧地或雜草叢生地之菇類 (13)，杜氏等 (2) 之研究中記載其食用價值爲 1879 年 Peck 氏所報告。本省於 1979 年首次由杜氏等 (2) 在稻草堆肥之培養材料中栽培成功 (圖1.) 。但其最適之生長條件尙未被瞭解，所以產量不理想，而各種菇類 (如洋菇、香菇、草菇、木耳、鮑魚菇及金針菇等) 其菌絲之生長及形成子實體之條件 (包括溫度、濕度、光線、培養材料之酸鹼度及成份) 均不盡相同 (1, 3, 4, 5, 6, 7, 12)，因此本研究之目的在探討這些環境因子及培養基材料對 *L. naucina* 菌絲生長之影響，並尋找最適合於生長之條件，作爲栽培之依據。

材料及方法

一、供試菌株：本試驗所採用之菌株係筆者於69年採自霧社草地，由 *L. naucina* 之子實體經純粹培養後保存於農試所植物病理系。

二、供試培養基：本試驗中所採用之培養基分成固體及液體二種：固體部份均採用 potato dextrose agar (PDA) ，液體部份則包括 GMY medium (glucose 10g, malt extract 10g, yeast extract 2g, distilled water 1 litre) ，與由下列物質所組成之培養液；即 sodium nitrate, calcium nitrate, ammonium nitrate, NH_4-tatarate, monopotassium phosphate, dipotassium phosphate, magnesium sulfate, potassium chloride, ferric chloride, calcium chloride, ferric phosphate, glucose, maltose, sucrose, corn meal, soluble starch, yeast extract, peptone, tryptone, 及 nutrient broth (表1.) 。

三、菌絲生長與溫度之關係：將直徑 5 mm 之菌絲塊移入直徑 9 cm之 Difco PDA 平板培養基中央，每皿加入 10 ml 培養基，置於 4 、8 、12、16、20、24、28、32、36 及 40 °C 之恆溫箱中培養，每處理 4 重複，經過 10 天後觀察並量取菌落生長之直徑。

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2.本所植物病理系助理研究員。臺灣省 臺中縣 霧峰鄉。

四、光線與菌絲生長之關係：將直徑5 mm 之菌絲塊置於直徑 9 cm 之 PDA 平板中央後，分別以（1）連續光照（500 lux）；（2）連續黑暗（以黑色塑膠布包裹培養皿）；（3）12 小時光照12 小時黑暗處理。上述處理在 24 °C 恆溫箱培養經過 10 天後測其菌落直徑。

五、酸鹼度與菌絲生長之關係：GMY 培養液以 1N NaOH 及 0.1 N HCl 調整，其經殺菌後 pH 值分別爲 4.2、5.3、5.8、6.3、6.8、7.2、7.8、8.4、9.2及10.0 等 10 種，而後將直徑 5 mm 之菌絲塊移入，在室溫（24°C）下振盪培養14天後測其菌絲乾重量。

表1. 各培養基配方之組成及用量

Table 1. Constitutions and rates of the various media in this experiment.

成份 Constituent \ 濃度(克／100毫升) Concentration (g/100ml)	培養基代號（medium）								
	A	B	C	D	E	F	G	H	I
Sodium nitrate	2.0	—	—	—	—	—	—	—	—
Calcium nitrate	—	—	2.0	2.0	2.0	—	—	—	—
Ammonium nitrate	—	2.0	—	—	2.0	—	—	—	—
NH_4-tatarate	—	—	—	—	0.5	—	—	—	—
Monopotassium phosphate	—	0.46	1.0	1.0	1.0	—	—	—	—
Dipotassium phosphate	1.0	1.0	—	—	—	—	—	—	—
Magnesium sulfate	0.5	0.5	0.5	0.5	0.5	—	—	—	—
Potassium chloride	0.5	—	0.5	0.5	0.5	—	—	—	—
Ferric chloride	—	0.01	—	—	0.01	—	—	—	—
Calcium chloride	—	0.2	—	—	—	—	—	—	—
Ferric phosphate	0.01	—	0.01	0.01	—	—	—	—	—
Glucose	—	30.0	—	—	—	30.0	—	10.0	10.0
Maltose	—	—	30.0	—	—	—	30.0	—	—
Sucrose	30.0	—	—	30.0	30.0	—	—	—	—
Corn meal	—	—	—	—	—	—	—	10.0	—
Malt extract	—	—	2.0	—	—	—	—	—	—
Soluble starch	—	—	—	—	—	—	—	—	10.0
Yeast extract	—	1.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Peptone	—	—	2.0	2.0	2.0	—	—	—	—
Tryptone	—	—	—	—	2.0	—	—	—	—
Nutrient broth	—	—	—	8.0	8.0	—	—	—	—

表 2. 以麥芽糖與硝酸鈣調配成不同比例之碳氮比

Table 2. Maltose and calcium nitrate contained in the media of different C/N ratio

C/N ratio	1	10	20	30	40	50	60	70	80	90	100
Maltose (g/l) Contained	0.56	5.6	11.2	16.8	22.4	23.0	33.6	39.2	44.8	50.4	56
Carbon (g/l) Contained	0.236	2.360	4.720	7.080	9.440	11.80	14.16	16.52	18.88	21.24	23.60
$Ca(NO_3)_2 \cdot 4H_2O$ Contained (g/l)	2	2	2	2	2	2	2	2	2	2	2
Nitrogen (g/l) Contained	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236	0.236

Note : Maltose ($C_{12}H_{22}O_{11}$), Mwt 360.31, Carbon Contained 42.1%=151.69g

$Ca(NO_3)_2 \cdot 4H_2O$, Mwt. 236.1, Nitrogen contained 11.8%=2 7.86g

(from reference 10)

六、培養液容量與菌絲生長之關係：於 250 ml 之三角瓶中裝入 40、60、80、100、120、140 及 160 ml 之培養液 C（表1.），殺菌後，每瓶移入一塊直徑 5 mm 之菌絲塊，經三週之振盪培養後，取出過濾，置於 60 °C 之乾燥箱24小時，測其菌絲乾重量。

七、培養基成份對菌絲生長之影響：以不同之碳源、氮源、營養物質及化學物質組成不同之配方，分別配成代號爲 A、B、C、D、E、F、G、H 及 I 9 種培養液（如表1.），將菌絲塊移入裝有 100 ml 培養液之 250 ml 三角瓶中，在室溫（24—28 °C）下，振盪培養 14 天後，取出過濾並稱其菌絲乾重量。

八、碳氮比（C/N ratio） 對菌絲生長之影響：以 maltose 及 $Ca(NO_3)_2$ 爲碳源及氮源，依照 Chen's (9) 之方法，分別配成 C/N 比例爲 1、10、20、30、40、50、60、70、80、90 及 100，其組成如表2.，培養14天後測其菌絲乾重量。

九、菌種材料對菌絲生長之影響：以稻桿堆肥（compost），麥粒（wheat grain），雜木鋸屑（sawdust），甘蔗爐泥顆粒菌種（granules of filter cake）及玉米（corn seed）作爲菌種材料，並調整其含水量均在55%，而後裝於兩頭均爲中空之玻璃管中（內徑 2.8 cm，長度 22cm），兩頭並以打孔之橡皮塞塞住，而後將菌絲塊分別由兩頭移入，置於 24 °C 下培養，14天後測其菌絲伸展長度，並比較各菌種材料之優劣。

結　果

一、溫度試驗：*L. naucina* 菌絲生長溫度爲 12—32 °C，超過 36 °C 或低於 8 °C 則停止生長。而以 24 °C 爲最適合生長之溫度，菌落直徑在 24 °C 下培養 10天後爲培養 5 天時之 3 倍（圖2.）。

二、光線與菌絲生長之關係：在長期光照下不利於菌絲之生長，黑暗下反而有利於菌絲之生長，且半光照和光照間之差別亦大（表3.）。

表 3. 光照對菌絲生長之影響：

Table 3. Effect of light on the mycelial growth of *L. naucina.*

處理 Treatment	菌落直徑[a]（公分） Colong diameter (cm)	
連續光照 (Continuous light)	2.34	a
12小時光照 (12 hrs alternating light)	2.74	b
連續黑暗 (Continuous darkness)	3.24	c

a. 小寫部份英文字母相同者爲依 Duncan 氏多變域測驗法，在 LSD 1 %下不顯著者。
The small letters represent Duncan's multiple range groupings of treatments that do not differ significantly at the 0.01 level.

三、pH 值對菌絲生長影響試驗；pH 值影響菌絲生長，由圖 3 可知其生長範圍極爲廣泛，pH 5.3～9.2 均適合，但以 pH 7.2～7.8 爲最適合，由此推知其較適合生長於微鹼性之基質。

四、液量試驗：培養液量之多寡對菌絲生長有影響，菌絲經液體震盪培養21天後，形成均勻之球狀菌絲塊（圖 4）。在 250 ml 之三角瓶中，以 100 ml 之液量爲最優（表4.），而此時各三角瓶中之 pH 值由原來之 pH 6.3 降到 5.5，但在不同處理間之 pH 值變化極小。

表 4 培養液量對菌絲生長之影響

Table 4. Effect of medium amount on the mycelial growth of *L. naucina.*

處理 Treatment	液量（毫升） Volume of medium (ml)						
	80	60	80	100	120	140	160
菌絲乾重量（毫克／每瓶） mycelium dry wt. (mg/flask)	243	258	345	543	333	292	283
最終 pH 值 final pH value	5.5	5.4	5.5	5.5	5.5	5.5	5.6

五、不同菌種材料對菌絲生長之影響：以 5 種材料當作基質來培養 *L. naucina* 之菌絲時，發現以麥粒培養時最佳，其次依序爲堆肥，玉米，顆粒菌種及鋸屑，在培養14天後，麥粒菌種之菌絲生長速度爲鋸屑菌種之 2 倍（表5.及圖5.）。

表 5 菌種材料對菌絲生長速度影響之比較

Table 5. Comparison of mycelial growth of *L. naucina* on different materials.

材料 material	麥粒	堆肥	玉米	顆粒	鋸屑
菌絲長度[a]	5.47	5.25	4.59	3.70	2.75
length of mycelium (cm)	a	a	b	c	d

a. 小寫部份英文字母相同者爲依 Duncan 氏多變域測驗法在 LSD 1 %下不顯著者 The small letters represent Duncan's multiple range grouping of treatment that do not differ significantly at the 0.01 level.

六、不同基質配方對菌絲生長之影響：在 9 種不同配方中，包括有鹽類、氮源及碳源等，其中以配方 C、H 及 I 等較適合菌絲之生長（圖 6），配方 A 及 I 中僅包括澱粉、醣類及酵母抽出液，而配方 C 中則包括一些微量元素及酵母抽出液，由圖六可知單糖比雙糖適合該菌之生長，且酵母抽出液爲該菌生長所必需之營養物。Czapeck's medium (medium A) 並不適合該菌之生長。

七、不同碳氮比對菌絲生長之影響：在11種不同碳氮比之液體培養基中以 C/N ratio 30 所得之菌絲乾重量爲最多（圖 7）。

討　論

一般菇類之菌絲生長均有其最適，最高及最低之溫度及酸碱度，如草菇（*Volvariella volvacea*）之菌絲生長最適條件爲 34°C, pH 在5.0（8）；香菇（*Lentinus edodes*）爲 24°C, pH 在 4.5～6.0（6）；洋菇（*Agaricus bisporus*）爲 24°C, pH 在6.8～6.9；*Boletus edulis* 爲 25°C, pH 在 5.38（4）；高溫菇（*Agaricus bitorquis*）爲 30°C, pH 在 5.1～7.0（3）；金針菇（*Flammulina velutipes*）則爲 24°C, pH 在 6.0（5）。由此可知食用菇中其菌絲生長之適合溫度及酸碱度之差異很大。而 *L. naucina* 之最適生長溫度即爲 24°C，且於 8°C 與 32°C 時生長完全停止，24°C 時之菌絲生長長度爲 20°C 時之2倍，爲 32°C 時之 1.5 倍，由此可知其生長適溫較洋菇爲略高。適合本菌之菌絲生長 pH 值變化不大，在 pH 5.3～9.2時均適其生長，但以 pH 7.8爲最適合。當 pH 值低於 4.5 時或高於10時則菌絲生長緩慢，而在 pH 5.8 至 7.2間菌絲乾重變化不大。液量之試驗以 100 ml 爲最適合生長之液量，在 250 ml 三角瓶中，若其培養液超過 100 ml 則菌絲生長量反而減少，此可能係因三角瓶之空間減少所致，由此推測其對通氣之需求較一般菇類爲敏感。光線對菌絲生長有抑制作用，即在菌絲生長期間不需光照，此和許多菇類有相似之處。*L. naucina* 原生於草地上，但在菌種培養時仍以麥粒及堆肥爲最適合其生長之基質，鋸屑及顆粒菌種則不適合，而在初步之試種結果以堆肥栽培可以正常出菇（2），若能在栽培條件及方法上加以改良則有大量栽培之前途。而營養之需求亦爲菌絲生長條件之一，其不外乎對碳源及氮源之利用，如草菇生長時以聚果膠酸鈉鹽（Na-polypectate）之利用爲最佳之碳源，而以麩醯胺（glutamine）及天冬素（Asparagine）爲最佳之氮源；但其菌種之培養則以棉籽作材料爲最優良（9.11）；而在金針菇則最適合其菌絲生長之糖類爲葡萄糖（dextrose）及乳糖（galactose）（5）。在韓氏等（10）之報告中所用之培養液（本試驗之 medium C）亦較適合 *L. naucina* 之生長，因此推斷其營養需求與草菇相近。另 *L. naucina* 菌絲生長之 C/N ratio 最適合條件爲 30，與草菇不同（C/N ratio 爲60），而與洋菇（C/N ratio 爲30）相近。

圖1. *L. naucina* 於堆肥栽培時所產生之子實體
Fig. 1. Fruiting bodies of *L. naucina* produced from compost.

圖2. 在不同溫度下，培養5天及10天後 *L. naucina* 之菌絲生長情形。
Fig. 2. Colony diameter (cm) of *L. naucina* grown 5 and 10 days at various temperatures.

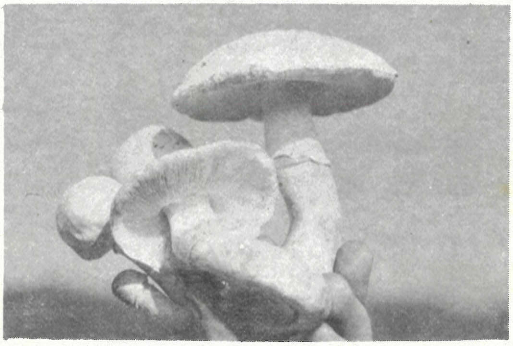
圖3. 培養於不同 pH 之 GMY 培養液14天後之 *L. naucina* 之菌絲乾重（mg）。
Fig. 3. Mycelial dry weight (mg) of *L. naucina* grown 14 days in GMY medium with various pH value.

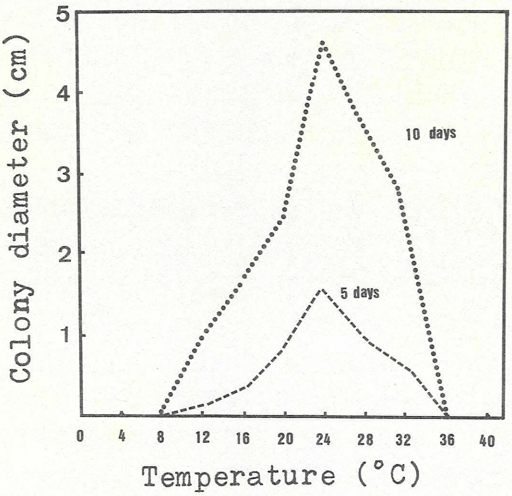
圖4. *L. naucina* 於液體培養基 C 中振盪培養21天後所產生之球形菌絲塊。
Fig. 4. Glob-like mycelium of *L. naucina* in liquid medium C, after shaking for 21 days.

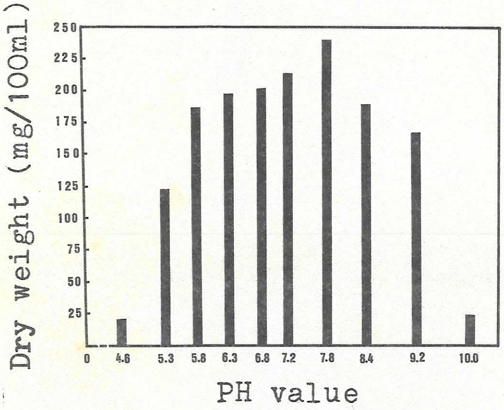
圖5. *L. naucina* 菌絲在不同菌種材料之生長情形，（Co：堆肥；W：麥粒；S：鋸屑：G；顆粒菌種；C：玉米）。
Fig. 5. The mycelial growth of *L. naucina* on Compost (Co); Wheat grain (W); Sawdust (S); granules of filter cake (G) and corn seed (C).

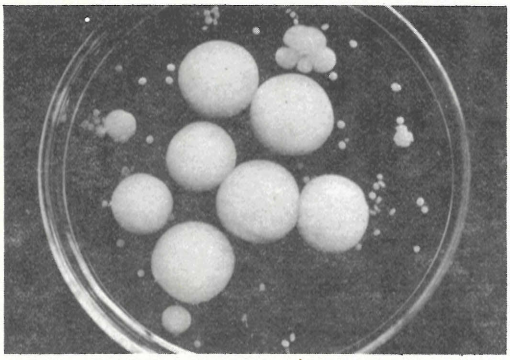
圖6. 比較不同液體培養基配方對 *L. naucina* 菌絲生長之影響（於 24°C 下培養14天）。
Fig. 6. Comparison of mycelial growth of *L. naucina* in different liquid media (after 14 days incubation at 24°C)

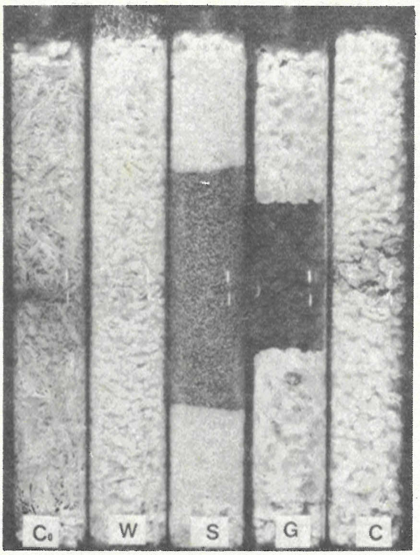
圖7. 不同碳氮比對 *L. naucina* 菌絲生長之影響，（於 24°C 下培養14天）。
Fig. 7. Effect of C/N ratio on mycelial growth of *L. naucina* in liquid medium (after 14 days incubation at 24 °C)

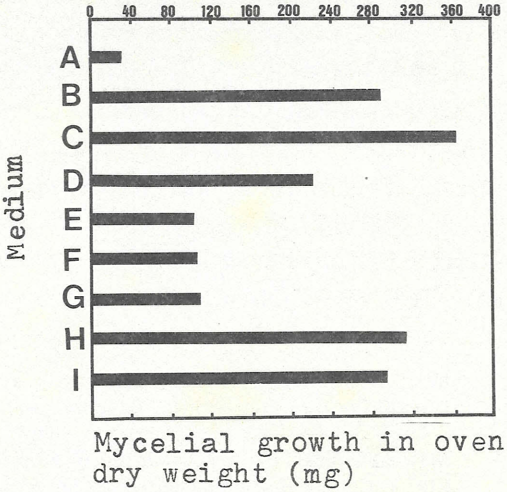


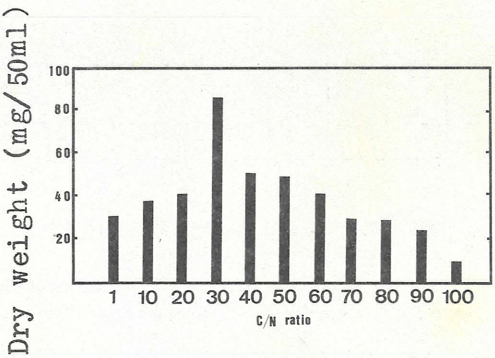












圖一 Fig. 1	圖五 Fig. 5
圖二 Fig. 2	圖六 Fig. 6
圖三 Fig. 3	圖七 Fig. 7
圖四 Fig. 4	

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Effect of Light, Composition of Medium, pH, and Temperature on the Mycelial Growth of *Lepiota naucina* [1]

Ying-ming Liao[2]

Summary

Potato dextrose agar (PDA) was used to evaluate the effect of light and temperature on the mycelial growth of *Lepiota naucina* Fr.. No growth was observed lower than 8°C or higher than 36°C (optimal 24 °C). Continuous darkness was found better than continuous light or 12-hrs alternating photoperiod. In a liquid medium, pH values ranged betweed 4.6 and 10.0 were tested and the mycelial growth was observed from 5.3 to 9.2 (optimal 7.8). The mycelial growth was found best on wheat grain among the 5 media tested for spawn. Among the nine liquid media, the highest mycelium dry weight was recorded in a 250 Erlenmeyer flask containing 100ml of medium C consisting calcium nitrate, monopotassium phosphate, malt extract, yeast extract, magnesium sulfate, ptassium chloride, ferric phosphate, maltose and peptone. The C/N ratio at 30 was found best for the mycelial growth of *L. naucina.*

1. Contribution No. 1090 from Taiwan Agricultural Reserch Institute.
2. Assistant Plant Pathologist, Department of Plant Pathology; TARI, Wufeng, Taichung Hsien, Taiwan 431, ROC.

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Insecticide Resistance Study in *Plutella xylostella* (L.)

III. The Insecticide Susceptibilities and Resistance Response of a Native Susceptible Strain. [1]

by

Tao-mei Chou and Edward Y. Cheng[2]

Abstract : The toxicity information of twenty-two insecticides on the diamondback moth was obtained by testing a native susceptible I-lan strain. Top five insecticides of all tested compounds are synthetic pyrethroids. Decamethrin is the most effective insecticide and carbaryl is the worst one. Mevinphos and carbofuran are the most effective compound for organophosphates and carbamates respectively. The overall result of toxicity test of I-lan strain is quite comparable to that of a susceptible strain introduced from France. Carbofuran can rapidly induce the resistance developed in the diamondback moth with only minor cross resistance problem in other insecticides. Fenvalerate induced the resistance at a rate slower than that of carbofuran, but it caused severe cross resistance in the moth. Cartap can only induce the resistance at a very slow rate and result in a moderate cross resistance problem. Both the cartap-resisted and the fenvalerate-resisted strains responded to fenvalerate and decamethrin in a similar fashion but were different from cypermethrin and permethrin.

In the general survey of insecticide resistance in the diamondback moth, *Plutella xylostella* (L.), a strain from I-lan found to be very sensitive to insecticides [2], and was used to study the insecticide susceptibilities and resistance development. We pressed the strain with several commonly used insecticides to induce the resistant strains, and then examine the scope and the extent of cross resistance of different resistant strains when they were tested against other insecticides.

Carbofuran, cartap and fenvalerate, three officially recommended insecticides in the diamondback moth control [5], were tested in this study. We hoped that the information obtained will help the plant protection personnel to compare the advantage and disadvantage of an insecticide before it was used in the field. Particularly, results of cross resistance investigation will help us to choose a good substitute to replace the ineffective insecticide in a resistance-proned area.

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2. Project assistant and senior entomologist, Dept. of Applied Zoology, TARI. Wufeng, Taichung, Taiwan 431, Rep. of China.

We also hoped that the collective knowledge of this and future studies will provide enough information for us to set up a rational insecticide substitution sequence for the diamondback moth control, and to prevent or slow down the resistance development in field strains.

Materials and Methods

The IL-strain diamondback moth of our 1980–81 collection was chosen for the study because of its high sensitivity to insecticides. All insecticides used in this study were commercial products and their formulations were listed in Table 1. For the resistance induction, carbofuran, cartap and fenvalerate were used to press three sub-lines of IL-strain. In the sensitivity and cross resistance tests, twenty-two insecticides registered for the diamondback moth control [10] were used. All formulated insecticides were diluted in the distilled water and sprayed within the Burkard Spray Tower. The spraying operation was the same as that of our previous study [2].

表1. 二十二種殺蟲劑對宜蘭品系小菜蛾之毒效測定

Table 1. The toxicities of twenty-two insecticides to the I-lan strain diamondback moth.

Insecticides & formulations	LC_{25}	LC_{50} (in ppm)	LC_{75}	Slope
Decamethrin 2.8% E. C.	1.18	3.58	1.1×10^{1}	0.605
Fenvalerate 20% E. C.	2.96	8.28	2.3×10^{1}	0.656
Permethrin 10% E. C.	6.25	1.4×10^{1}	3.0×10^{1}	0.853
Cypermethrin 5% E. C.	7.28	1.9×10^{1}	5.3×10^{1}	0.678
UCX-33 34% E. C.*	2.5×10^{1}	6.3×10^{1}	1.6×10^{2}	0.735
Mevinphos 25.3% E. C.	5.9×10^{1}	7.3×10^{1}	1.8×10^{2}	1.213
Profenofos 43% E. C.	4.5×10^{1}	1.0×10^{2}	2.3×10^{2}	0.834
Carbofuran 40.6% W. P.	2.0×10^{1}	1.2×10^{2}	6.9×10^{2}	0.383
Prophos 70.6% E. C.	1.1×10^{2}	1.7×10^{2}	2.6×10^{2}	1.576
Cyanophenphos 25% E. C.	7.7×10^{1}	1.9×10^{2}	4.4×10^{2}	0.775
Diethquinalphion 25% E. C.	1.0×10^{2}	2.3×10^{2}	5.0×10^{2}	0.833
Methidathion 40% E. C.	1.6×10^{2}	2.7×10^{2}	4.4×10^{2}	1.339
Cartap 98% P.	1.4×10^{2}	2.9×10^{2}	5.8×10^{2}	0.974
Tokuthion 50% E. C.	1.7×10^{2}	3.1×10^{2}	5.6×10^{2}	1.125
Mephosfolan 25% E. C.	1.4×10^{2}	3.6×10^{2}	9.0×10^{2}	0.735
Methamidophos 50% S.	2.2×10^{2}	5.6×10^{2}	1.4×10^{3}	0.716
Phenthoate 50% E. C.	2.6×10^{2}	6.7×10^{2}	1.7×10^{3}	0.713
Chlorpyrifos 40.8% E. C.	3.4×10^{2}	7.7×10^{2}	1.7×10^{3}	0.829
Methomyl 24% S.	1.7×10^{3}	3.4×10^{3}	7.1×10^{3}	0.924
Fenitrothion 50% E. C.	5.4×10^{3}	8.7×10^{3}	1.4×10^{4}	1.432
Malathion 50% E. C.	7.4×10^{3}	1.6×10^{4}	3.2×10^{4}	0.904
Carbaryl 85% W. P.	6.8×10^{3}	2.7×10^{4}	1.1×10^{5}	0.491

*Permethrin formulated by Union Carbide.

The sensitivity test : For every tested insecticide, seven dosage levels within the range of LC_{10} to LC_{90} were made in distilled water, and each concentration was tested on forty to sixty third-instar diamondback moth larvae. Results of the tests were analyzed in probits.

The induction of resistant strains : Usually one thousand diamondback moth larvae were sprayed with selected insecticide at the dosage of LC_{75}, and subsequently survived insects were collected for propagating the next generation. The LC_{75} level was re-determined for each generation on 100—200 early emerged larvae of that generation.

The rate of LC_{75} level increase from generation to generation was counted as the resistance development rate for that insecticide in the diamondback moth.

The cross resistance test : Once the resistance of a pressed strain had reached a significant level, usually to a range of 10 to 20 folds in the resistance ratio, the strain was then subjected to the same sensitivity test again. Newly obtained LC_{75} of various insecticides in the resistant strains were compared to that of IL-strain to detect any possible occurrence and extent of cross resistance.

Results

The toxicities of twenty-two registered insecticides to the IL-strain diamondback moth were reported in Table 1, and the order was arranged according to the effectiveness. Of all tested insecticides, decamethrin and carbaryl were the most and the least effective compound with the LC_{50} at 3.58ppm and 2.7×10^4ppm respectively. Five top insecticides on the list were synthetic pyrethroids, mevinphos and carbofuran were the most effective compound for organophosphates and carbamates and their LC_{50} were 73ppm and 120 ppm respectively.

The results were further compared and calibrated to the result of Liu et al [8], and the comparison were tabulated in Table 2. The response of IL-strain to four synthetic pyrethroids, commonly tested in both studies, matched perfectly to that of FSstrain, a susceptible strain introduced from France, in Liu's study. However the sensitivity of IL-strain to organophosphates was much lower than the FS-strain. The PH-strain is the native susceptible strain in Liu's study but its response in the synthetic pyrethroids were quite different from both FS-strain and our IL-strain. Instead, the most effective insecticide was permethrin and the same fact was also demonstrated in the BC-strain or a native resistant strain used by them.

Although methomyl has been considered as a good insecticide in controlling the diamondback moth [4], its effectiveness was not up to the standard as expected in both the FS-strain and the IL-strain.

Cartap showed stronger killing action toward the IL-strain than the FS-strain when decamethrin was referred as the common standard in Table 2. Since the cartap resistance has not developed and spread significantly [2], its effectiveness has also been confirmed in the PH-strain in Liu's study, and we believed that cartap is still an effective insecticide and can be used for the diamondback moth control.

Tokuthion is very effective toward the FS-strain [8] but was not so desirable when

表2.、試以第滅靈爲標準，比較劉明毅等研究之 FS. PH. BC 三品系與吾人研究之 IL 品系小菜蛾毒效資料。

Table 2. The comparison of insecticide sensitivity (LC_{50}) of I-lan strain to Liu's result [8] in referring decamethrin as the common standard.

Insecticides	IL	FS	PH	BC
Decamethrin	1.0[a]	1.0[b]	1.0[c]	1.0[d]
Fenvalerate	2.3	2.0	1.1	2.5
Tokuthion	86.6	2.0	14.8	5.4
Permethrin	3.8	4.0	0.3	0.2
Cypermethrin	5.5	5.0	2.0	2.1
Cyanofenphos	53.1	10.0	13.1	> 220.0
Mevinphos	20.4	—	—	—
Methyl parathion	—	23.5	4,468.5	> 220.0
Profenofos	27.9	—	—	—
Carbofuran	33.5	—	—	—
Prophos	47.5	—	—	—
Dichlorvos	—	84.0	65.2	11.3
Cartap	81.0	125.0	36.0	11.1
Malathion	4,469.0	137.0	1,396.0	> 220.0
Diazinon	—	146.5	114.4	27.1
DDT	—	174.0	1,991.0	> 220.0
Methomyl	949.7	253.0	316.2	119.0
Propoxur	—	1,690.0	$>10^4$	> 220.0
Carbaryl	7,541.9	2,160.0	910.0	> 220.0

1.0[a]=3.58ppm, 1.0[b]=0.2ppm, 1.0[c]=11.10ppm, 1.0[d]=447ppm
the testing method of (*a*) is different from (*b*), (*c*) and (*d*).

it was tested against three Taiwan strains (Table 2). Several insecticides were definitely not suitable for the diamondback moth control any longer in Taiwan and they were methomyl, malathion and carbaryl.

The response of diamondback moth to the selection pressure at the LC_{75} level of three insecticides were different (Fig. 1). The moth responded to carbofuran most drastically and developed 36 folds of resistance in merely eight generations. Two other insecticides also induced the resistance but at much slower rates, and they were 15 folds for fenvalerate in 12 generations and 10 folds for cartap in 10 generations. Of three tested insecticides, cartap has the lowest capability in inducing the resistance.

The cross resistance of three artificially induced resistant strains to other registered insecticides were studied and were presented in Table 3. The carbofuran-resisted strain showed very little cross resistance to other nineteen insecticides. On the

Fig. 1. The induction rates of resistance in the diamondback moth by carbofuran, fenvalerate and cartap at the selection pressure of LC_{75}.

圖1. 加保扶，芬化利及培丹誘發小菜蛾抗性能力之比較

抗藥性誘發反應速率

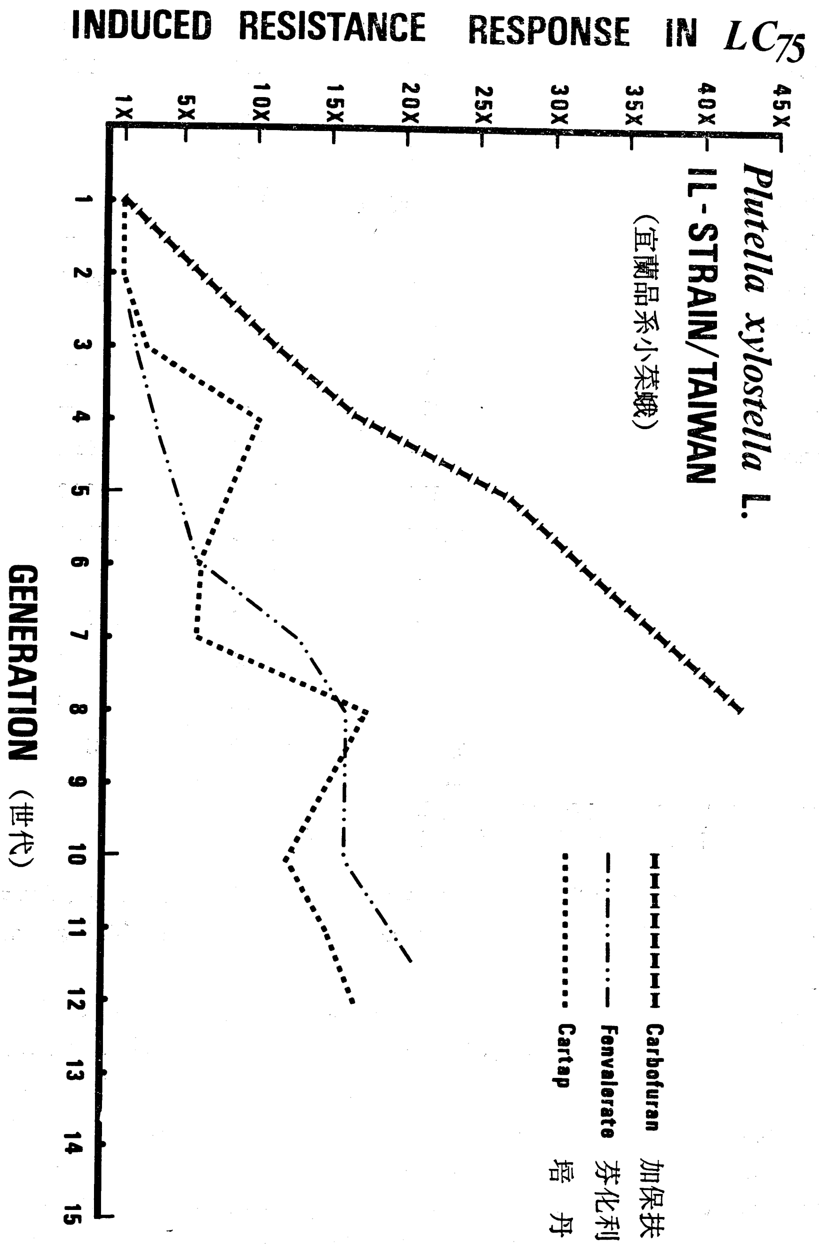

Table 3. The cross-resistance of three artificially induced resistant strains of diamondback moth to twenty-one other insecticides.

表 3. 人工誘發三種小菜蛾抗性品系對其他21種殺蟲劑之交互抗性測定

Insecticdiees	Carbofuran-resis.		Fenvalerate-resis.		Cartap-resis.	
	LC_{75}*	R. R.	LC_{75}*	R. R.	LC_{75}*	R. R.
Carbofuran	2.5×10^4	36.23	4.4×10^3	6.38	2.2×10^3	3.19
Fenvalerate	4.1×10^1	1.78	3.3×10^2	14.34	1.1×10^2	4.78
Cartap	2.3×10^3	3.97	2.9×10^3	5.00	5.6×10^3	9.66
Decamethrin	1.8×10^1	1.64	1.2×10^2	10.91	5.7×10^1	5.18
Permethrin	9.3×10^1	3.01	1.0×10^2	3.30	4.2×10^1	1.83
Cypermethrin	—	—	2.3×10^2	4.34	—	—
UCX-33	—	—	1.4×10^2	0.88	—	—
Mevinphos	5.9×10^2	3.28	6.7×10^2	3.72	4.6×10^2	2.56
Profenofos	7.9×10^1	0.34	5.0×10^2	2.17	4.3×10^2	1.87
Prophos	1.1×10^2	0.42	8.3×10^2	3.19	3.8×10^2	1.46
Cyanophenphos	1.2×10^2	0.27	1.6×10^3	3.64	1.5×10^3	3.41
Diethquinalphion	3.1×10^2	0.62	4.1×10^3	8.20	5.1×10^2	1.02
Methidathion	4.5×10^2	1.02	1.3×10^3	2.95	6.4×10^2	1.45
Tokuthion	3.0×10^2	0.54	2.1×10^3	3.75	1.1×10^3	1.96
Mephosfolan	9.6×10^2	1.07	7.3×10^2	0.81	4.3×10^2	0.48
Methamidophos	1.0×10^3	0.71	1.9×10^3	1.36	1.5×10^3	1.07
Phenthoate	1.1×10^3	0.65	4.2×10^3	2.47	1.3×10^3	0.76
Chlorpyrifos	3.0×10^3	1.76	8.0×10^3	4.71	5.6×10^3	3.29
Methomyl	5.7×10^3	0.80	1.5×10^4	2.11	5.4×10^3	0.76
Fenitrothion	2.3×10^4	1.64	1.0×10^5	7.14	1.7×10^4	1.21
Malathion	2.3×10^4	0.72	4.5×10^4	1.36	1.7×10^4	0.52
Carbaryl	9.8×10^4	0.93	1.3×10^5	1.24	6.4×10^4	0.61

* PPM

other hand, stronger cross resistance were observed in both the cartap-resisted and the fenvalerate-resisted strains. The cartap-resisted strain became less sensitive to decamethrin, fenvalerate, cyanophenphos, chlorpyrifos and carbofuran. In the fenvalerate-resisted strain , strong response of resistance to both fenvalerate and decamethrin were again observed. Besides, a universal increase in resistance at various degree against other insecticides were appeared in the fenvalerate-resisted strain. Most significantly, the susceptibility dropped sharply in regard to diethquinalphion, fenitrothion, cartap, chlorpyrifos, cypermethrin, tokuthion and cyanophenphos.

Discussion

The reason of diamondback moth can survive under the heavy pressure of chemical control is because they can build up the resistance very fast (1,2,3,4,6,7,8). Before other control measures become practical, the increasing demand in vegetable production still depends heavily on the usage of insecticides. Besides, we felt that an insecticide should be continually investigated for its side-effects and undesirable consequence when it was recommended for the field application.

The result of this study has indicated that in the diamondback moth, the resistance induction rate and the extent of cross resistance were different from one insecticide to others. Since the effective longevity of an insecticide in field application is in inverse ratio to its resistance induction rate, and to select a substituting insecticide depend on how much we know about the scope and extent of cross resistance of that resistant strain, it is unavoidable that more research is needed to reshape the chemical control scheme of diamondback moth in Taiwan.

The superiority of synthetic pyrethroids in the sensitivity aspect has been clearly demonstrated, and how to preserve their effectiveness in the threat of resistance is a very important matter and the subject has been intensively investigated by Sun (9) currently. Of four studied synthetic pyrethroids, the diamondback moth responded to fenvalerate and decamethrin in a similar fashion, and responded to cypermethrin and permethrin more closely. It seems that the α-cyano group is not the only functional group which causes the difference, and more research is needed in the mechanism study to explain the cross resistance difference in relation to the molecular structures.

Carbofuran is the most toxic compound of three carbamates tested in the sensitivity study, unfortunately, the undesirable nature of its resistance inducing ability has excluded the only carbamate which was good in the diamondback moth control.

In organophosphates, mevinphos, profenofos and tokuthion are three most promising compounds and they were currently been investigated in our laboratory in the aspect of resistance.

Cartap is still a fair choice as the control agent for the diamondback moth, and can be recommended in many areas in Taiwan.

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小菜蛾抗藥性之研究

III.對三種殺蟲劑之抗性發展及引發之交互抗性[1]

周桃美　鄭　允[2]

本試驗係利用本所於民國69—70年間於宜蘭所採得之感性品系小菜蛾 *Plutella xylostella* (L)，測定22種登記於防治此蟲之殺蟲劑的基本毒理資料。所測得最有效之前五種均屬人工合成除蟲菊精（Synthetic pyrethroids)，而其中，又以第滅靈（Decamethrin）最爲有效。數種有機磷劑效果均佳，但以美文松爲第一，氨基甲酸鹽類之效果均不理想，僅加保扶尚可，加保利爲所有供試藥劑中感度最差者（見表1.）。總體而言，所測得結果與劉明毅等人所測之 FS-品系反應類似（見表2.）。但宜蘭品系對有機磷類殺蟲劑之感度偏低，似與該類藥劑已在本省使用多年，可能有某種程度之抗藥性發生有關。

在抗藥性誘發試驗中，係以加保扶，培丹及芬化利等三種殺蟲劑之百分之七十五致死濃度（LC_{75}）進行汰選，各世代所需用之 LC_{75} 隨汰選次數而增加，故每代均需重新測定，吾人係以各世代需用之 LC_{75} 增加速率爲該藥劑誘發抗藥能力之指標（見圖1）。一旦抗性品系之抗藥力達十至二十倍時，即可進行交互抗性之測定，測定仍依基本毒理測定方式進行，將所得結果與原有宜蘭品系毒理資料比較，以檢查各抗藥性品系對不同殺蟲劑之交互抗性是否發生及發生程度。

所得結果顯示，加保扶誘發抗藥能力最强，經過8世代之汰選，可誘發36倍抗藥能力。芬化利則次之，12代即可誘發15倍之抗藥力。三種供試殺蟲劑中，以培丹之抗性誘發能力最低，經10代僅誘發約10倍之抗藥力。

抗加保扶品系僅對其他殺蟲劑產生輕微或全無交互抗性，因此，如需於田間換用其他藥劑對付抗加保扶之小菜蛾時，選藥範圍較寬。抗芬化利者，則完全不同，其交互抗性範圍廣泛，程度較嚴重。抗培丹者居中，只對部分殺蟲劑發生中等程度之交互抗性（見表3.）。

由以上結果，可預測使用不同化學防治藥劑時，小菜蛾之可能反應，因而選用較理想之藥劑進行防治。

1.臺灣農業試驗所　研究報告第1091號。本計畫承國科會補助（編號 72-0409-B055-03），簡珠碧、簡淑貝協助工作，劉清博士協助統計分析僅一併致謝。

2.本所應用動物系研究助理及研究員。臺灣省 臺中縣 霧峰鄉。

中華農業研究（Jour. agric. Res. China）32(2)：155～160（1983）

粒狀殺蟲劑對西瓜生育初期害蟲防治試驗[1]

温宏治　　李錫山[2]

摘要：應用粒狀殺蟲劑防治數種西瓜害蟲之結果顯示，各供試藥劑防治臺灣大蟋蟀效果均佳，其中以 Thimet 10% G 及 Temik 10% G 最優，次爲 Terracur-P 5% G, Furadan 3% G 及 Contraven 10% G；防治棉蚜以 Furadan 3% G 與 Temik 10% G 效果最優，藥效約50～70 天，其他藥劑則爲 30～50 天之間；淡色薊馬以 Temik 10% G 及 Furadan 3% G 效果最優，藥效於 30～50 天之間；供試藥劑對葉潛蠅均具防治效力，其中以 Furadan 3% G、Contraven 10% G、Temik 10% G 及 Disyston 5% G 等藥效較優；神澤氏葉蟎以 Temik 10%G 效果最優，藥效可維持至 70 天左右，其餘藥劑防治效果較差。

爲害西瓜之害蟲頗多，其中生育初期之主要害蟲有臺灣大蟋蟀（*Brachytrupes portentosus* Lichtenstein)、棉蚜（*Aphis gossypii* Glover)、葉潛蠅(*Liriomyza* sp)、黃守瓜(*Aulacophora similis* olivier)、淡色薊馬（*Thrips flavus* Frank）及神澤氏葉蟎（*Tetranychus kanzawi* kishida）。臺灣大蟋蟀屬雜食性，其發生與前期作物種類及土壤性質有密切關係，如前期作爲花生、甘藷、豆薯、菸草……等，而土壤屬砂質地，較易發生[5]。棉蚜寄主多，終年發生，但以乾旱季節發生較嚴重，爲瓜類毒素病之主要媒介昆蟲[3]。葉潛蠅主要發生於苗期，潛行於葉肉內食害，可致葉片枯萎，影響植株生育初期的發育[7,8]。黃守瓜其成蟲爲害葉部，幼蟲則土棲食害根部，於新墾之園地發生較多[4]。淡色薊馬近年來爲害瓜類似有增加的趨勢，尤其於高溫乾旱季節容易造成猖獗[6]。神澤葉蟎於西瓜栽培中、末期，往往嚴重爲害，其主要原因乃係早期濫施殺蟲劑所致。以上害蟲均於西瓜種植初期即開始發生，故如能於早期作有效防治，把害蟲棲羣密度壓低，將有助於西瓜生育後期之防治。本試驗之目的係在利用粒狀殺蟲劑之經濟、對天敵無直接毒害及對授粉昆蟲安全等優越條件[1,239]，針對西瓜數種害蟲進行防治比較試驗，探討各種粒劑對各種害蟲之防治功能，試驗所得有效藥劑及方法，俾供農友防治之參考。

材料與方法

本試驗分二試區進行，第一試區於民國70年11月～71年2月設於臺南縣玉井鄉，第二試區於民國71年2月～5月設於高雄縣鳥松鄉。供試作物爲西瓜，供試之8種粒狀殺蟲劑，與1無施藥對照共計9處理，小區面積 3 m×6 m＝18 m²，每小區種5株，採逢機完全區集設計，四重複，每種殺蟲劑係按每公頃 3,000 株計算分二次施藥。第一次在定植前施用，爲全藥量之⅓。藥量秤妥後分別裝入塑膠袋，每株一包，於整地後將每一塑膠袋自下角剪一小孔，粒劑即由小孔中撒出，均勻撒施於定植穴中，施藥後覆土3公分，再定植西瓜苗，全區定植後傍晚引水灌溉，至土壤濕潤爲度。定植後10天再施

1.臺灣省農業試驗所 研究報告第1092號。本試驗承羅幹成副研究員鑑定葉蟎，林珪瑞先生鑑定潛蠅，謹此深致謝忱。

2.本所鳳山熱帶園藝試驗分所植物保護系助理研究員、副研究員兼系主任。臺灣省 高雄縣 鳳山市。

藥一次，施用全藥量之⅔，施於植株旁約15公分周圍土面，然後用灑水桶灑濕土面，以免藥劑飛揚。施藥量如下附表：

附表

藥劑名稱 Insecticide	施用量及方法 Dosage and method of application		
	kg/ha	第一次穴施 1st furrow	第二次側施(g/plant) 2nd side dressing
3%加保扶粒劑 (Furadan G)	30	5	10
5%毒絲本粒劑 (Dursban G)	36	3	6
10%托福松粒劑 (Contraven G)	18	1.5	3
5%大福松粒劑 (Dyfonate G)	36	3	6
10%得滅克粒劑 (Temik G)	18	1.5	3
10%福瑞松粒劑 (Thimet G)	18	1.5	3
5%二硫松粒劑 (Disyston G)	36	3	6
5%繁福松粒劑 (Terracur-p G)	36	3	6

臺南玉井及高雄鳥松試區分別於70年12月8日及71年2月10日施藥及定植，第二次施藥後10、30、50、70及90天各調查一次。

調查方法——臺灣大蟋蟀：施藥後第10天調查被害株（包括切株或被囓葉柄緣），並計算株旁30公分範圍內蟋蟀穴數。棉蚜：施藥後第10、30、50、70天計算每株總葉數，與蚜蟲為害之葉數。葉潛蠅：施藥後第10天計算每株總葉數，與葉潛蠅為害之葉數。黃守瓜幼蟲：施藥後第10天檢視枯死瓜株之根部，是否受黃守瓜幼蟲蛀食所致。淡色薊馬：施藥後第10、30、50、70天調查每株嫩心（1～4枚），計算薊馬成、幼蟲數。神澤葉蟎：施藥後第50、70、90天檢視每株中、老葉5～10枚，計算葉蟎（每葉3隻幼、成蟎以上）為害之葉數[8]。

結果與討論

（1）臺灣大蟋蟀防治效果：

臺灣大蟋蟀之成蟲、稚蟲皆喜歡取食幼小作物，常將幼莖齊地面嚙斷，拖入穴內食之。本蟲屬夜出性昆蟲，活動力强。第一試區前作係為花生，土質屬砂質地，蟋蟀密度因而較高，效果較顯著，而第二試區前作係甘藍，土質屬壤土，蟋蟀密度極低，無法顯示藥效。由表1得悉，施藥株附近穴數顯著的減少，其中以 Temik 10% G 及 Thimet 10% G 最少，唯 Tmik 10% G 處理區雖無發現洞穴，苗株仍遭為害，蓋蟋蟀活動力强，可能受對照區之蟋蟀干擾所致，故數種藥劑比較應以 Thimet 10% G 及 Temik 10% G 防治本蟲效果最佳，次為 Terracur-p 5% G、Furadan 3% G 及 Contraven 10% G。

（2）棉蚜防治效果：

二試區均於種植後一週，即發現有翅雌蚜蟲飛來葉上行胎生繁殖。各種粒劑對棉蚜防治至30天時效果均佳，如表2所示，至50天時部份藥劑顯著下降，唯以第一試區之 Furadan 3% G 及 Dursban 5% G 及第二試區之 Furadan 3% G、Contraven 10%G 及 Temik 10% G 效果較佳，70天時大部份藥劑已不見效果，如以50天評定二試區之防治效果，應以 Furadan 3% G 與 Temik 10% G 防治效果最佳。

表1. 粒狀殺蟲劑防治西瓜臺灣大蟋蟀效果（第一試區民國70年11月）

Table 1. Effectiveness of granulated insectides against *Brachytrupes portentosus* on watermelon (Experimental field I. Nov. 1981)

Treatment	Dorsage (kg/ha)	holes of cricket / 20 plants	plant infested / 20 plants	percent control
1. Furadan 3% G	60	3	1	88.89
2. Dusban 5% G	36	4	3	66.67
3. Contraven 10% G	18	3	1	88.89
4. Dyfonate 5% G	36	2	1	88.89
5. Temik 10% G	18	0	2	77.78
6. Thimet 10% G	18	0	0	100
7. Disyston 5% G	36	4	3	66.67
8. Terracur-p 5% G	36	2	1	88.89
9. Check (Untreated)		14	9	—

表2. 粒狀殺蟲劑防治西瓜棉蚜效果（第一試區民國70年11月～71年2月，第二試區71年2～5月）

Table 2. Effectiveness of granulated insecticides against cotton aphid on watermelon (Experimental field I, Nov. 1981-Feb. 1982, field II Feb. -May 1982)

Treatment	Dorsage (kg/ha)	% of leaves infested[a]							
		10 DAT[b]		30 DAT		50 DAT		70 DAT	
		Field I	Field II	F I	F II	F I	F II	F I	F II
1. Furadan 3% G	60	0 a	0 a	0.8 a	5.3 bc	1.5 ab	8.1 ab	11.4 ab	10.3 a
2. Dursban 5% G	36	0 a	1.3 a	0.6 a	6.3 bc	0.8 a	15.6 cd	5.9 a	14.4 a
3. Contraven 10% G	18	1.3 a	0 a	1.6 ab	5.3 bc	4.8 b	8.1 ab	12.4 ab	27.6 bc
4. Dyfonate 5% G	36	0 a	1.3 a	3.1 ab	7.3 bc	2.9 ab	12.6 bc	9.6 ab	20.8 ab
5. Temik 10% G	18	0 a	0 a	0.6 a	2.2 a	2.3 ab	4.4 a	9.9 ab	12.6 a
6. Thimet 10% G	18	0 a	0 a	1.3 ab	4.2 ab	2.2 ab	10.5 bc	9.2 ab	18.8 ab
7. Disyston 5% G	36	0 a	3.3 b	2.9 ab	8.4 c	3.8 ab	23.3 de	8.6 ab	11.3 a
8. Terracur-p 5% G	36	1.3 a	0.6 a	4.1 b	8.3 c	5.3 b	24.8 e	13.2 b	28.7 c
9. Check (Untreated)		7.4 b	12.3 c	17.4 c	38.7 d	17.7 c	59.3 f	28.4 c	44.8 d

a) Number followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

b) DAT : Days after treatment.

（3）淡色薊馬防治效果：

二試區均於種植後二週即有些處理遭受該蟲爲害，由表 3 得悉，第一試區各種粒劑防治淡色薊馬之效果，約可維續至50天。70天時效果顯然降低，第二試區薊馬密度高，此乃受鄰近廢耕茄子園薊馬遷移所致，至30天時密度已很高，至50天時各種藥劑已乏防治效果。由二試區比較，各粒劑對本蟲藥效介於30至50天之間，其中以 Furadan 3% G 及 Temik 10% G 效果最佳。

表 3. 粒狀殺蟲劑防治西瓜淡色薊馬效果（第一試區民國70年11月～71年 2 月，第二試區71年 2 ～ 5 月）

Table 3. Effectiveness of granulated insecticides against *Thrips flavus* on watermelon (Experimental field I, Nov. 1981-Feb. 1982, field II Feb.-May 1982)

Treatmeat	Dorsage (kg/ha)	No. of thrip/5 shoots [a]							
		10 DAT		30 DAT		50 DAT		70DAT	
		Field I	Field II	F I	F II	F I	F II	F I	F II
1. Furadan 3% G	60	0	0 a	0 a	8.5 a	0 a	24.8 ab	5.0 ab	30.3 a
2. Dursban 5% G	36	0	0.5 a	0 a	14.5 b	0.5 a	27.8 abc	10.3 b	41.3 bc
3. Contraven 10% G	18	0	0.8 a	0.3 a	15.0 b	0.5 a	28.8 abc	9.3 b	40.8 ab
4. Dyfonate 5% G	36	0	0 a	0 a	12.5 ab	0.5 a	19.8 a	5.0 ab	31.3 a
5. Temik 10% G	18	0	0 a	0 a	9.5 ab	0.5 a	24.8 ab	4.3 a	36.8 ab
6. Thimet 10% G	18	0	0 a	0.3 a	13.5 ab	0.5 a	32.3 bc	8.8 ab	43.3 bcd
7. Disyston 5% G	36	0	1.0 a	0.3 a	12.0 ab	1.0 a	31.0 bc	9.3 b	44.8 cd
8. Terracur-p 5% G	36	0	0.3 a	0 a	14.5 b	0.8 a	36.0 cd	8.0 ab	36.3 ab
9. Check (Untreated)		0.75	8.5 b	4.8 b	33.5 c	6.8 a	44.8 d	19.1 c	48.8 d

a) Number followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

（4）葉潛蠅防治效果：

葉潛蠅爲害西瓜較不普遍，第一試區未發生，而第二試區亦於栽培早期發生，以後西瓜成長快，爲害則不顯著，由表 4 顯示一般藥劑防治本蟲均具效力，其中以 Furadan 3% G、Contraven 10%G Temik 10% G 及 Disyston 5% G 之效果最好。

表4. 粒狀殺蟲劑防治西瓜葉潛蠅效果（第二試區民國71年 2 月）

Table 4. Effectiveness of granulated insecticides against leaf miner on watermelon (Experimental field II Feb. 1982)

Treatment	Dorsage (kg/ha)	% of leaves infested	percent control
1. Furadan 3% G	60	0	100
2. Dursban 5% G	36	0.13	98.21
3. Contraven 10% G	18	0	100
4. Dyfonate 5% G	36	0.02	99.73
5. Temik 10% G	18	0	100
6. Thimet 10% G	18	0.01	98.86
7. Disyston 5% G	36	0	100
8. Terracur-p 5% G	36	0.15	97.74
9. Check (Untreated)		7.28	—

（5）神澤葉蟎防治效果：

近年來本省西瓜栽培中末期常遭神澤葉蟎爲害，由表5知悉，各藥劑對神澤葉蟎之防治效果，至70天時兩試區以 Temik 10% G 最好，90天時各種藥劑效力減退，而第二試區於 90天防治率回昇原因，係該次調查前連續下雨數天，致使葉蟎棲羣密度大減。

表5. 粒狀殺蟲劑防治西瓜上神澤葉蟎效果（第一試區民國70年11月～71年2月，第二試區 71 年2～5月）

Table 5. Effectiveness of granulated insecticides against *Tetranychus kanzawai* on watermelon (Experimental field I Nov. 1981-Feb. 1982, field II Feb.-May 1982)

Treatment	Dorsage (kg/ha)	% of leaves infested [a]					
		50 DAT		70 DAT		90 DAT	
		Field I	Field II	F I	F II	F I	F II
1. Furadan 3% G	60	0 a	20.2 c	8.7 a	36.0 c	16.3 bc	22.0 f
2. Dursban 5% G	36	1 a	7.3 a	5.6 a	30.4 abc	18.3 c	7.4 a
3. Gontraven 10% C	18	2 a	10.3 ab	11.2 ab	22.3 a	20.3 de	12.4 d
4. Dyfonate 5% G	36	2 a	9.8 ab	9.9 a	32.8 bc	15.3 ab	9.3 bc
5. Temik 10% G	18	2 a	10.4 ab	4.9 a	20.4 a	18.3 c	8.4 ab
6. Thimet 10% G	18	1 a	15.2 b	11.5 ab	24.1 abc	19.3 cd	10.2 c
7. Disyston 5% G	36	0 a	18.3 bc	10.0 ab	22.5 ab	13.7 a	16.7 e
8. Terracur-p 5% G	36	1 a	17.4 bc	12.7 ab	25.0 abc	19.3 cd	22.6 f
9. Check (Untreated)		10 b	41.7 d	19.3 b	52.3 d	22.4 e	31 g

a) Number followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

綜觀上述試驗，除黃守瓜未發生，無法對該蟲作防治之試驗外，應用粒狀殺蟲劑防治西瓜生育初期害蟲效果顯著，唯各粒劑殺蟲之殘效性均不能持續至西瓜栽培後期，且因殘毒問題，後期不宜施用粒劑，是故對後期發生之葉蟎或其他害蟲，須作地面施藥加以防治，至於早期施用粒劑防治西瓜害蟲，是否有殘毒問題，仍須進一步試驗探討。

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Effects of Granular Insecticides on the Control of Some Pests during Early Growth Stage of Watermelon Plants [1]

Hung-chich Wen and Hsi-shan Lee [2]

Summary

The purpose of this experiment was to evaluate the effectiveness of several ganular insecticides in controlling the pests infestating on young watermelon plants. One-third of the insecticide was applied into planting holes prior to planting and the other two-thirds was side-dressed 10 days after permanent planting. The infestation of several pests was investigated at 10, 30, 50, 70 and 90 days after the second application of the insecticides.

Thimet 10% G and Temik 10% G were most effective in controlling Taiwan giant cricke (*Brachytrupes portentosus*) followed by Terracur-P 5% G, Furadan 3% G and Contraven 10% G. Furadan while 3% G and Temik 10% G were effective in controlling cotton aphid (*A. gossypii*) and the effect could persist for 50 to 70 days. All the tested insec ticides showed an effect of 30 to 50 days in controlling thrips (*Thrips flavus*). The most significant results were observed on the application of Furadan 3% G and Temik 10% G. Furadan 3% G, Contraven 10% G were effective in reducing the population of leaf miner (*Liriomyza* sp.) while Temik 10% G was the most effective insecticide in controlling the red mite (*Tetranychus kanzawai*) for up to 70 days after planting.

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1. Contribution No. 1092 from Taiwan Agricultural Research Institute.

2. Assistant entomologist and entomologist and head, respectively, Department of Plant Protection, Fengshan Tropical Horticultural Experiment Station, TARI, Fengshan city, Kaohsiung Hsien, Taiwan 830, R. O. C.

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柑橘缺硼症之診斷與防治方法之研究[1]

邱再發　張淑賢[2]

摘要：民國65年10月底獲知東勢鎮有一椪柑及柑桶園發生病態果實，果型變小、堅硬如石、剝開則絨層變硬加厚，瓣囊縮小退化而無汁，但果樹之枝葉生長仍然正常。此症狀疑似缺硼症，經採取該園之果實及其上方之春梢葉片之樣品進行分析，結果顯示葉片與果皮中硼含量均在 10 ppm 以下，遠低於 Chapman 等氏所提之正常濃度範圍 (25—150 ppm)，故推斷此一異常係缺硼所致。爲進一步證實之，並探討安全之硼素施用量與施用方法及覆草對硼素吸收之影響，並觀察施硼之殘效，乃自66年至70年間進行試驗，處理分爲（1）對照，不施硼（2） 土壤施用硼酸 40 g／株（3）土壤施用硼酸 120 g ／株（4）0.3%硼酸液每年葉面噴施兩次（5）土壤施用硼酸 40 g／株＋0.3%硼酸液葉面噴施（6）土壤施用硼酸 40 g／株＋覆草20公分等。試驗結果摘述如下：

1.試驗果園之土壤熱水可溶性硼含量低，表土 (0—15 cm) 含 0.15 ppm，底土 (15—30 cm) 含 0.10 ppm。當乾旱之年缺硼症即發生，此時葉片及果皮中之硼濃度均在10 ppm左右。但雨量充足之年則無缺硼症發生，此時八月之春梢非結果枝葉片含硼20 ppm左右，果皮含 14 ppm。若於果實肥大期缺硼，則異常之石頭柑發生；若於春梢萌發至開花結果期缺硼，則結果量低。

2.春梢非結果枝葉片中之硼含量隨葉齡增加而增加，即老葉硼濃度高於新葉。但缺硼之柑樹，無論新葉或老葉硼含量均低。

3.在10年生、中細質地土壤之缺硼柑園，於樹冠下之土壤表面撒施 40—120 g／株硼酸，可安全矯正缺硼症，且其殘效可維持四年以上。硼酸施用之當年，葉片磷濃度隨硼酸施用量之增加而降低，兩者之負相關顯著。故於類似本試驗園條件之缺硼柑園，宜施 50 g／株之硼酸以防治缺硼，且一次施用，四年內不宜再施。惟此用量應視樹齡及土壤質地而調整。

4.每年於葉面噴施兩次0.3% 硼酸液（亦可矯正缺硼症），但葉片中硼濃度逐年增加。或因噴施液掉落於土壤而殘留之故，因此葉面噴施不宜連年施行。

5.土壤熱水可溶性硼含量亦反應土壤施硼量，所施硼酸有自表土向底土移動之趨勢。

民國65年10月底，臺中青果合作社來函告知東勢鎮林阿秋農友之椪柑及桶柑園，自64年起於果樹上發生病態果實，果型變小，堅硬如石頭，剝開則絨層變硬加厚，瓣囊退化縮小且無汁，但果樹之枝葉生長仍然正常，希望能予以診斷矯正。

上述之果實異常症狀與Chapman等氏 (5) 及 Shrorrocks 氏 (12)，所描述之柑橘果實缺硼症狀相似，乃前往該園採取果實及葉片進行分析，發現葉片中之硼含量在 10 ppm 以下，遠低於 Chapman (5) 編著書中所歸納之葉片硼素正常濃度範圍 (25—150 ppm)，因此推斷該異常係缺硼所致。爲進一步證實，乃自 66 年 1 月起於林氏之果園進行硼素施用試驗。鑑於作物對硼素之容忍範圍很窄 (5,10)，不足則缺乏，施用過多則引起毒害；又據 Wilson 等氏 (14) 之報告，硼素施於中細質地之土壤，則多累積於表土；而乾旱之季節作物更易發生缺硼 (5,7,10,11,15)。因此本試驗乃探討硼素之施用適量與施用

1.臺灣省農業試驗所　研究報告第1093號。

2.臺灣省茶葉改良場場長（原本所農化系研究員）、本所農化系助理研究員。臺灣省　臺中縣　霧峰鄉。

方法及覆草保持水分等對防治缺硼之效果，並繼續觀察施硼之殘效，以期提供柑橘缺硼之診斷與安全之防治方法。

材料與方法

一、症狀之診斷：

由於病態果係局部發生，同一果樹上之果實其果型差異很大（見表二），因此65年11月自林氏之異常果園分別採取果型正常與果型異常之果實，及果實上方之春梢葉片，分析果皮及葉片中之硼含量，並與採自其他地區正常柑園之樣本相較。

二、田間試驗：

自民國66年1月始至70年1月止計四年之田間試驗，設六處理、四重複，逢機區集設計，每小區三棵樹，中間設保護樹一株。試區內多數均爲椪柑，僅少數爲桶柑，樹齡均爲10年生。供試果園位於坡地，階段種植，無灌溉設施。果園土壤屬礫石地、强酸性、熱水可溶性硼含量很低，如表1所示。

表1. 供試果園土壤之理化性質

Table 1. Soil properties of experimental orchard.

深 度 Dept (cm)	質 地 Texture	pH (soil=H_2O=1：1)	CEC meg/100g sot	Total N %	O. M. %	Avail. P ppm	Avail. K ppm	Hws B* ppm
0—15cm	C. L	4.0	17.0	0.20	2.40	100	180	0.14
15—30cm	C. L	3.9	16.7	0.18	2.10	37	140	0.08

*：Hws B：熱水可溶性硼含量（Hot water soluble boron）

處理內容爲：

1.對照（Check）：僅施5號複肥 5 kg/tree/year

2.Soil H_3BO_3 40 g/tree：硼酸 40 g／株，撒施於樹冠下之土壤表面。

3.Soil H_3BO_3 120 g/tree：硼酸 120 g／株，施法同處理2。

4.Spray 0.3% H_3BO_3：0.3% 硼酸水溶液，每年於4月及6月各葉面噴施一次。噴施量爲每三株數 10 *l*（66年1月14日多噴一次，69年僅噴一次。）

5.Soil H_3BO_3 40g/tree+Spray 0.3%H_3BO_3：硼酸 40 g／株土施及0.3%液葉面噴施兩次。

6.Soil H_3BO_3 40g/tree+Mulch：硼酸 40 g／株土施及覆草20公分以保持水分。

土壤撒施硼酸之處理，均於66年1月14日施用，此後即不再施用，以繼續觀察其殘效。

三、調查及分析項目：

每隔兩個月採取春梢非結果枝第三或第四葉做爲樣本，分析大量要素及硼素含量之經時變化。每半年採取1、2及3處理之土壤測定其熱水可溶性硼含量。收穫期調查果實產量及品質。

大量要素依本研究室慣用法分析，葉片硼含量測定則以 0.5 g 樣品+25 ml 0.5 N HCl 振盪 2 hr，濾液以 Curcumine 呈色[16]。土壤熱水可溶性硼含量測定則按 Jackson 氏[8]之方法。

結果與討論

一、缺硼柑園之果皮及葉片中硼含量：

由表2可見，取自異常果園果實，無論果型大小，其果皮均厚，小果型者達44%。而分析結果（見表3）亦顯示無論果型大小，異常柑園之果皮及其上葉片之硼含量均在 10 ppm 左右，正常果園則葉片平均含硼 40 ppm，果皮含 17 ppm。再與 Chapman 著書中[5]所歸納之標準相較，則落於硼

缺乏範圍，因此推斷此一異常係缺硼所致。

表2.：異常柑園之果實重與果皮厚度

Table 2. fruit weight and peel weight of the fruits taken from abnormal ordard.

	果重 Fruit Weight g/one Fruit	果皮重 Peetweight g/one fruit (%)	
桶柑 果型正常	134.9	47.7	35.4
桶柑 果型異常	61.5	27.3	44.4
椪柑 果型正常	150.7	45.5	30.2
椪柑 果型異常	51.4	22.6	42.8

表3.正常柑園與異常柑園之葉片及果皮硼濃度比較 (ppm)

Table 3. Comparison of boron concentration of leaf and fruit peel between the normal and abnormal ordard.

樣本號 Sample No.	正常果園（椪柑） Normal		異常果園（椪柑及桶柑） abnormal	
	葉片 Leaf	果皮 Fruit peel	葉片 Laef	果皮 peel
1	31.4	16.3	11.2	9.5 （桶柑果型正常）
2	40.2	17.9	8.7	10.5 （桶柑果型正常）
3	53.5		8.7	9.5 （桶柑果型異常）
4	30.9		10.0	9.5 （桶柑果型異常）
5	35.4		11.2	9.7 （椪柑果型正常）
6	36.1		11.2	7.0 （椪柑果型異常）
Mean	40.6	17.1	10.2	9.3

二、施硼處理對果實品質與產量之影響：

民國66年底收穫時，各處理均未見小果型之石頭柑，但對照區之結果很少，產量極低，平均僅18 kg/tree；其餘各施硼處理則獲得顯著增產（見表4）。土壤施硼處理之增產效果較噴施者（處理4）爲佳覆草對果實產量無影響。品質分析結果（見表6）顯示本年度之果實果皮均厚（30%），其中以對照區之果皮最厚，果汁率最低，糖、酸度則處理間無顯著差異。

民國67年至69年度，對照區之果實產量與果型均恢復正常，因此各處理間之產量與品質均無顯著差異。（如表5表6所示，限於篇幅、僅列出66及68兩年之品質分析結果）。

土壤水分影響養分之吸收與移動，當乾旱時，作物根自土壤中吸收養分之速率降低，而表土較底土易於乾燥，因此根自表土吸收養分之速率最受影響；再者，一般而言表土之硼含量高於底土，因此許多報告指出，在同一土壤，當水分充足時未見缺硼，或症狀輕微，但乾旱時則缺硼嚴重發生

表4. 施硼處理對缺硼柑園果實產量之影響（66年度）

Table 4. The effect of boron application to the fruit yields of boron deficient citrus orchard. (1977, kg/tree)

處理 Treatments \ 重覆 Replications	I	II	III	IV	平均 Mean	指數 Index
1. Check	33.9	16.0	8.7	13.9	18.1	(100)
2. Soil H_3BO_3, 40g/tree	59.1	33.8	30.6	18.0	35.4	(196)
3. Soil H_3BO_3, 120g/tree	52.1	42.2	42.6	47.2	46.1	(255)
4. Spray 0.3% H_3BO_3	34.2	15.8	19.9	67.5	34.4	(190)
5. Soil H_3BO_3 40g/tree+Spray 0.3% H_3BO_3	57.9	45.4	49.1	23.3	43.9	(243)
6. Soil H_3BO_3 40g/tree+Mulch	55.1	35.1	42.3	17.0	37.4	(206)

表5. 施硼處理對缺硼柑園果實產量之影響（67年至69年，kg/株）

Table 5. The effect of boron application to the fruit yields of boron deficient citrus orchard. (1978–1980, kg/tree)

年度 Year \ 處理 Treatment	1. Check		2. Soil H_3BO_3 40 g/tree		3. Soil H_3BO_3 120g/tree		4. Spray 0.3% H_3BO_3		5. Soil H_3BO_3 40g/tree+ Spray 0.3% H_3BO_3		6. Soil H_3BO_3 40g/tree+ Mulch	
1978	70.3	(100)	61.3	(87)	63.7	(91)	68.7	(98)	69.1	(98)	62.7	(89)
1979	61.3	(100)	60.1	(98)	63.4	(103)	65.0	(106)	65.2	(106)	64.1	(104)
1980	53.5	(100)	53.1	(99)	52.1	(97)	55.8	(104)	51.4	(96)	50.0	(94)

表6. 施硼處理對果實品質之影響（66年與68年度）

Table 6. The effect of boron application on the fruit quality. (1977 & 1979)

年 Year	處理 Treatment \ 品質 Quality	果重 fruit weight g/fruit	果皮率 percentage of peel weight to fruit weight (%)	果汁率 percentage of juice to fruit weight (%)	pH	糖度 % of sugar content	酸度 citricacid g/100 mljuice
1977	1. Check	181.5	32.4	44.6	3.71	13.7	0.663
	2. Soil H_3BO_3 40g/ tree	167.9	29.4	47.7	3.71	13.0	0.628
	3. Soil H_3BO_3 120g /tre	165.2	31.7	50.1	3.73	12.7	0.663
	4. Spray 0.3% H_3BO_3	162.5	28.9	46.0	3.61	14.2	0.787
	5. Soil H_3BO_3 40g/tre+ Spray 0.3% H_3BO_3	149.8	32.0	49.4	3.68	12.9	0.710
	6. Soil H_3BO_3 40g/tre+ Mulch	162.7	31.2	47.3	3.65	13.4	0.692
1979	1. Check	197.3	25.2	49.6	3.63	11.1	0.677
	2. Soil H_3BO_3 40g/tree	183.9	22.9	52.4	3.64	11.1	0.675
	3. Soil H_3BO_3 120g/tre	195.3	22.4	51.6	3.68	11.1	0.657
	4. Spray 0.3% H_3BO_3	185.2	23.6	45.6	3.65	11.1	0.693
	5. Soil H_3BO_3 40g/tre+ Spray 0.3% H_3BO_3	189.2	23.2	47.6	3.62	11.3	0.713
	6. Soil H_3BO_3 40g/tre+ Mulch	192.9	24.7	49.5	3.67	11.3	0.638

(5,7,10,11,15)。本試驗果園 0—15 cm 之表土僅含熱水可溶性硼 0.15 ppm, 15—30 cm 則僅含0.09ppm，因此乾旱之年缺硼症即發生，而雨量充足之年則否。根據石岡氣象站（較靠近東勢者）65年至69年之雨量資料顯示（自農業氣象旬報整理而得），65年度及66年度乾季期間（10月－4月）之降雨量顯著較其他年度爲低（見表7），自65年10月1日至66年5月10日間僅降雨 135.8 mm。而此期間正值65年度之果實肥大期及66年度之開花著果期，此或者可以用以解釋65年度有缺硼之小果發生，而66年度雖無異常之小果，但對照區之果實產量奇低之原因。據文獻載 (9)，硼素有利於花粉管之發育伸長，又 Batjer 氏 (2) 以 25—125 ppm 硼酸液噴施於梨花，可增加梨之結果率。據此，則66年度之對照區是否因缺硼而影響受粉，致使產量降低？實値進一步探討。

表7. 65年度至69年度乾季期間石岡地區之降雨量

Table 7. Precipitation of the dry season of 1975—1980 at the shihkang area.

期　間 Duration	降雨量 (mm) Precipitation
1975/10/10—1976/4/30	293.8
1976/10/1 —1977/5/10	135.8
1977/10/1 —1978/5/10	571.4
1978/10/1 —1979/5/10	436.2
1979/10/1 —1980/5/10	488.8

二、施硼處理對春梢非結果枝葉片硼含量、果皮硼含量與土壤中熱水可溶性硼含量之影響。

由表8及圖一可見春梢柑葉中之硼含量隨葉齡增加而增加，隨後又稍降。即老葉硼濃度高於新葉，此與 Brodford (3) 等 Embleton (6) 氏所報告者相同。

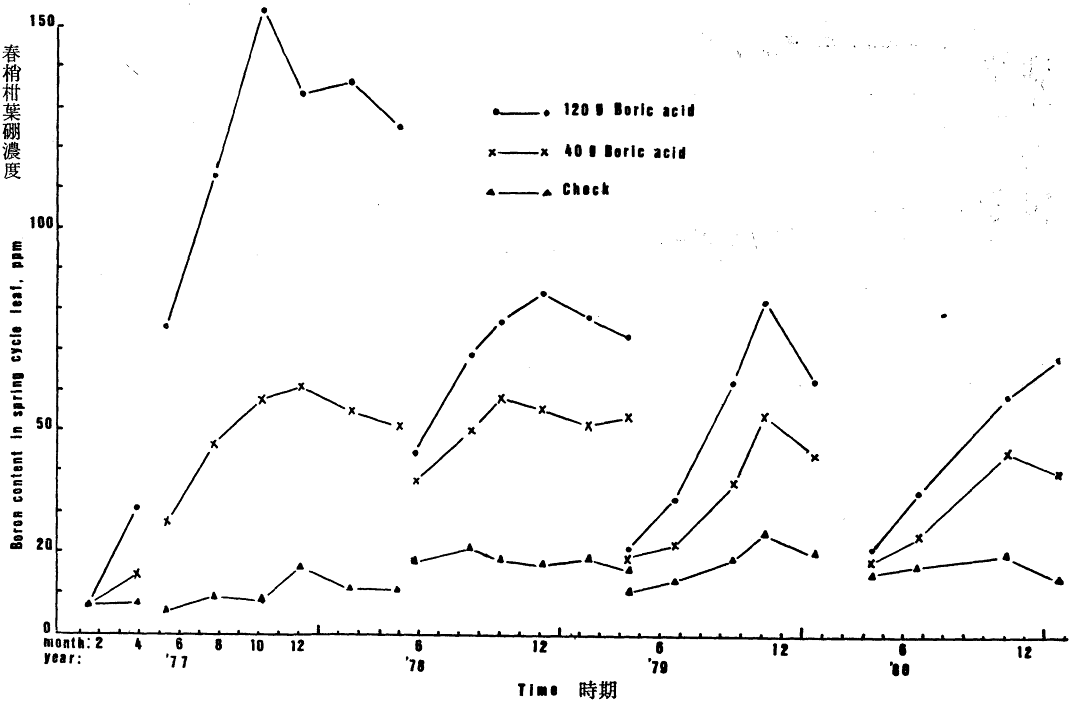
施硼前老葉中之硼含量僅 5—8 ppm，顯示嚴重缺硼。土壤施硼或葉面噴施後兩個月，葉片硼濃度即顯著較對照爲高，66年度萌發之春梢葉片硼濃度，處理間之差異更顯著，對照區在 5—16 ppm間，土施硼酸 120 g/tree 者濃度最高在 76—150 ppm 間，土施 40 g/tree 者在 30—60 ppm 間，土施 40 克／tree+0.3% 液噴施者在 32—69 ppm 間，覆草則對硼素吸收影響不大。此後土壤施硼處理之葉片硼含量即逐年遞減，但四年內均在標準濃度範圍內。但自67年至70年間，對照區之春梢葉片硼濃度則提高至 10—25 ppm，而果實而未見缺硼症狀。0.3硼酸液葉面噴施之處理（4及5），其葉片硼濃度則逐年提高，因此69年僅噴施一次。葉面噴施之用量爲每3棵樹 10 l，每年噴施兩次，除部分粘著於葉面外，其餘均落至土壤，因此四年內，亦相當於施用 80 g/tree，故而葉片硼含量逐年增加。

表8. 各施硼處理對春梢柑葉硼含量之影響（ppm）。

Table 8. The effect of boron application the boron content in spring cycyle leaves from non-fruiting terminals.

處理 Treatment / 採樣日期 Date of Sampling	1. Check	2. Soil H_3BO_3 40g/tree	3. Soil H_3BO_3 120g/tree	4. Spray 0.3% H_3BO_3	5. Soil H_3BO_3 40g/tree+ Spray 0.3% H_3BO_3	6 Soil H_3BO_3 40g/tree+ mulch
1977/1/14	5	8	6	6	6	8
3/23	7	15	31	37	13	12

5/13	5	27	76	12	32	29
7/24	9	47	113	13	38	45
10/7	8	58	154	12	55	66
12/3	16	61	134	30	69	51
1978/2/18	11	55	137	29	69	63
4/28	11	51	125	21	67	60
5/25	17	37	44	61	65	36
8/18	21	50	64	79	92	46
10/ 2	18	59	77	83	100	50
12/ 4	17	55	84	88	112	57
1979/2/13	19	51	78	74	95	55
4/13	16	54	73	68	93	51
4/13	10	19	21	17	20	18
6/22	13	22	33	62	82	24
9/18	18	37	62	156	167	53
11/3	25	54	82	121	135	51
1980/1/18	20	44	62	83	102	43
4/11	15	18	21	19	24	20
6/20	17	24	35	25	32	22
11/3	20	45	59	69	66	43
1981/1/20	14	40	69	63	59	38



圖一：不同施硼量之春梢柑葉硼濃度之經時變化

Fig. 1. Seasonal changes showing influence of leaf age and boron application rate on the concentrations of boron in leaves from nonfruiting twigs of spring cycle.

（果皮硼含量與反應施硼量）66年度對照區椪柑之果皮硼含量僅 12.0 ppm，桶柑則爲10.6 ppm，其餘各處理則在 15—21 ppm 間。67年度對照區之果皮硼含量已提高爲 14.2 ppm，雖較其他處理 (16—2.5 ppm) 爲低，但已接近正常數值（如表 9 所示）

表9. 施硼處理對果皮中硼含量之影響（ppm）

Table 9. The effect of boron application on the boron concentration in fruit peel.

年度 Years	品種 Variety	1. Check	2. Soil H_3BO_3 40 g/tree	3. Soil H_3BO_3 120 g/tree	4. Spray 0.3% H_3BO_3	5. Soil H_3BO_3 40g/tree+ Spray 0.3% H_3BO_3	6 Soil H_3BO_3 40 g/tree+ mulch
1977	椪柑	12.0	16.7	20.9	16.6	17.5	18.2
	桶柑	10.6	15.2	21.6	19.6	19.4	19.7
1978	椪柑	14.2	19.0	20.5	20.5	17.7	16.1

表10. 東勢缺硼柑園施硼後土壤熱水可溶性硼含量之經時變化

Table 10. Changes of hot water solube boron content in soils applied with different rates of boric acid.

處理 Treatment / 土壤深度 Depth of soil / 採樣日期 Date of sampling	1. Check			2. Soil H_3BO_3 40g/tree			3. Soil H_3BO_3 120g/tree		
	0—15 cm	15—30 cm	30—50 cm	0—15 cm	15—30 cm	30—50 cm	0—15 cm	15—30 cm	30—50 cm
'77/10/7	0.14	0.08	—	0.48	0.35	—	1.04	0.62	—
'78/5/25	0.15	0.14	—	0.72	0.39	—	1.09	0.62	—
'78/11/11	0.19	0.07	0.10	0.87	0.40	0.29	0.70	0.47	0.53
'79/5/4	0.13	0.04	0.04	0.39	0.28	0.28	0.66	0.37	0.35
'79/11/21	0.14	0.07	0.11	0.31	0.22	0.25	0.53	0.33	0.41
'80/11/3	0.13	0.09	0.09	0.25	0.20	0.32	0.32	0.31	0.31

土壤中熱水可溶性硼含量，如表 10 所示，對照區之表土四年內均在 0.15 ppm 左右，底土則在 0.10 ppm 左右。土壤施硼酸 40 g/tree，使表土提高至 0.50 ppm，然後逐年降低至 0.25 ppm。(67 年度高至 0.87 ppm，可能係採樣誤差）土施硼酸 120 g/tree，則使表土提高至 1.1 ppm，而後逐年降至 0.3 ppm。由施硼區不同深度土壤含量來看，硼酸有自表土向底土移動之趨勢。Baker 等氏[1]於砂質壤土至坋質壤土施硼 2—10 lb/acre，則其殘效可維 5 年之久。Wilson[14]等氏於 Cecrl Clay (CEC 7.2—5.3) 及 Norfolk sandy loam (CEC 3.6—4.7)，施用硼砂 40 lb/acre，則 6 個月後，在粘土則大部分硼素均殘留於20公分深表土內；在砂質壤土則表土內很少，大部分均移動至較深之土層內。在本試驗園，則施硼之殘效至少可維持四年以上。

三、春梢非結果枝葉片中大量要素含量之經時變化。

施硼處理僅對大量要素中之磷素含量有顯著影響，此一效應，僅在施用當年有顯著效果，在66年5月、7月、10月及12月所採樣品中，均顯出葉片中磷濃度與硼濃度有顯著負相關，限於篇幅，表11僅列出10月分之結果，此時葉片中之硼濃度亦達最高峰，兩著之相關係數達－0.809。

表11. 施硼處理對春梢非結果枝柑葉大量要素含量之影響。(% dry weight, 採自66年10月 7 日)

Table 11. The effect of boron application on the macro-element contents of spring cycle leaves from non-fruiting terminals sampled on 7th, October, 1977.

處　　理 Treatment	N	P	K	Ca	Mg	B
1. Check	3.42	0.136	0.774	3.63	0.218	8.0
2. Soil H_3BO_3 40g/tree	3.28	0.128	0.784	3.77	0.273	58.0
3. Soil H_3BO_3 120g/tree	3.42	0.106	0.711	3.95	0.251	154.0
4. Spray 0.3% H_3BO_3	3.34	0.130	0.938	3.45	0.231	12.4
5. Soil H_3BO_3 40g/tree+Spray 0.3% H_3BO_3	3.36	0.096	0.719	3.63	0.296	55.5
6 Soil H_3BO_3 40 g/tree+mulch	3.55	0.096	0.805	3.78	0.268	66.0

Smith & Reuther [13] 在 Valancia 之砂耕試驗中亦有相同之結果。施硼處理對其他要素及其他年度之磷濃度均無顯著影響，因此表12僅列出六處理之平均值。由表中可見葉片氮、磷、鉀及鎂含量隨葉齡增加而降低；鈣含量則反是，以老葉較高，此與一般研究結果相同 [6]。

表12. 春梢(非結果枝)柑葉之大量要素含量之經時變化

Table 12. Seasonal changes showing influence of leafage on the concentrations of macro elements in leaves from nonfruiting terminals of spring cycle.

採樣日期 Date of sampling \ 要素 Denants	N	P	K	Ca	Mg
	%				
1977/ 1/14	2.89	0.103	0.758	3.16	0.220
3/28	2.69	0.111	0.787	3.44	0.322
5/13	2.93	0.148	1.252	1.83	0.276
7/24	3.21	0.125	0.770	3.49	0.329
10/ 7	3.40	0.115	0.918	3.70	0.256
12/ 3	3.02	0.082	0.769	3.63	0.275
1978/ 2/18	2.91	0.104	0.883	3.32	0.258
4/28	2.84	0.091	0.750	3.83	0.231
5/25	3.39	0.155	1.673	2.14	0.296
8/18	3.38	0.123	1.124	2.63	0.245
10/ 2	3.34	0.129	1.011	2.99	0.238
12/ 4	3.21	0.112	1.133	2.68	0.278
1979/ 2/13	2.95	0.109	1.067	2.91	0.224
4/13	2.99	0.090	0.891	3.55	0.198

4/13	2.92	0.170	1.418	1.25	0.204
6/22	3.28	0.149	1.458	2.20	0.243
9/18	3.29	0.140	0.959	3.05	0.284
11/ 3	3.01	0.116	1.021	2.96	0.235
1980/ 1/18	3.17	0.121	1.188	3.00	0.263
4/11	2.85	0.159	1.538	1.37	0.219
6/20	3.38	0.132	1.370	2.55	0.254
11/ 3	2.89	0.117	1.097	3.38	0.236
1981/ 1/20	2.67	0.105	1.213	2.98	0.234

結　　論：

綜合上述結果可知，在土壤熱水可溶性硼含量低之椪柑與桶柑園（0—15 cm 含 0.15 ppm, 15—30 cm 含 0.10 ppm），當乾旱之年缺硼症即發生，其葉片及果皮中之硼濃度均在 10 ppm 左右。但雨量充足之年則無缺硼症發生，其八月份所採之春梢無結果枝葉片之硼含量仍低在 20 ppm 左右，果皮含硼 14 ppm 左右。若於果實肥大期缺硼，則異常之石頭柑發生；若於春梢萌發至開花結果期缺硼，則結果量低。

春梢非結果枝葉片中之硼含量隨葉齡增加而增加，即老葉中之硼含量高於新葉。但缺硼之柑樹，無論新葉或老葉硼含量均低。

在10年生，中細質地土壤之缺硼柑園，於樹冠下之土壤表面撒施 40—120 g/tree 之硼酸，可安全矯正缺硼症，且其殘效可維持四年以上，四年內葉片硼含量均在 25—150 ppm 之正常範圍內。硼酸施用之當年，葉片磷濃度隨硼酸施用量之增加而降低，兩者之負相關顯著。故於類似本試驗園條件之缺硼柑園，宜施 50 g／株之硼酸以防治缺硼，且一次施用四年內不宜再施。但此一用量應視樹齡、土壤質地而調整。

每年於葉面噴施兩次 0.3% 硼酸液，則葉片中硼濃度逐年增加，第三年之 8 月即高達 150 ppm，故葉面噴施不宜連年施行。

土壤撒施硼酸 400—120 g／株，提高土壤中之熱水可溶性硼含量及葉片與果皮中硼含量，且其濃度均反應施硼量。所施之硼酸有自表土向底土移動之趨勢。

在安全濃度範圍內，施硼量對於果實產量、品質、與大量要素含量（磷除外）均無顯著影響。

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A Study on Diagnosis and Correction of Boron Deficiency in the Citrus Orchard[1]

C. F. Chiu[2] and S. S. Chang[3]

Summary

Abnormal fruit of ponkang and tungkang in Tunghsi orchard were investigated in October, 1976, showing smaller size, thicker peel, less juicy and much harder than that of normal fruits. The leaf and peel B content were about 10 ppm which were much lower than the normal range of boron content (B 25—150 ppm) as indicated by the Chapman's standard. The cause of the abnormal fruits was expected to be boron deficiency. Therefore, a field experiment was layed out in order to clarify the effect and method of boron application with the following treatments : (1) Control, no boron applicated, (2) Boric acid 40 g/tree, by soil application, (3) Boric acid 120 g/tree, by soil application, (4) 0.3% boric acid solution, by foliar spray twice a year, (5) Boric acid 40g/tree plus foliar spray, (6) Boric acid 40 g/tree plus straw mulching. The leaf and soil boron contents with seasonal sampling were analyzed. The experimental results obtained were summarized as follows.

1. The hot water soluble B contents in the experimental field were low, that is, 0.15 ppm in surface soil (0—15cm) and 0.10ppm in subsoil (15—30 cm). The leaf and peel B contents were about 10ppm when the boron deficiency of citrus occurred in the dry year. It was 20ppm in leaves and 14ppm in peels when the precipitation was abundant during the year and no occurrence of boron deficiency was observed.

2. The B con tent in leaves from nonfruiting twigs of spring cycle increased with leaf age, that is, the B content was higher in old leaves than in young leaves. However, the B content was always low either in old leaves or in young leaves when boron was deficient in citrus trees.

3. Soil application of boric acid 40—120g/tree on citrus orchard with medium textured soil and 10-year-old trees was effective for correction of boron deficiency and its residual effect was maintained for more than 4 years. It was found that the P content in leaves decreased as the application amount of boric acid was increased. There was a significant negative correlation between the P and B content in leaves in the year of boric acid application. Boric acid 50 g/tree by soil application every four years was recommended for boron deficient orchards under the same soil conditions.

4. Foliar spray of 0.3% boric acid solution was also effective, however, considerable amount of boron were accumulated in the soil which was fallen from the continuous yearly-spray of boron. So, it is suggested that the foliar spray should not be done every year.

1. Contribution No. 1093 from Taiwan Agricultural Researc Instituteh.

2. Director of Taiwan Tea Experiment Station, Yangmei ; Taoyuan, Taiwan, ROC.

3. Asistant soil Scientist, Department of Agricultural Chemistry, TARI, Wufeng, Taichung, Taiwan, ROC.

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磷素肥料在土壤中的變化聚積及其被旱作利用之研究[1]

李　子　純[2]

摘要：本研究係於溫室進行，將多量磷肥（500 ppm P）分四次同時施入本省十二種不同土壤中，每次施入後，即經浸水、風乾處理約一個月，以摸擬田間情況。四次共歷時五個月。處理過的土壤（每土壤均包括一不施磷之對照）再進行 Neubauer 法磷效應試驗，種植作物為小麥。目的為探討及比較原土壤中磷素與施肥磷素之聚積型態；化學測定法有效磷值與眞正有效磷值間之關係，及施肥聚積磷素之回收率。其結果摘述如下：

1.原土壤中之磷幾乎全以Fe-P及Ca-P型態存在，前者在十二土壤中平均佔53.2%，後者佔44.8%，而以Al-P型態存在者僅佔三者總量之1.9%。在施用多量磷肥（500 ppm P)後之土壤中Al-P所佔的百分率升高為42.8%（十二土壤平均），Ca-P 減低為 17.6%，Fe-P 減低為 41.3%。又本試驗資料顯示施用磷肥 500 ppm P 後土壤中的磷絕大部分（84%）以 Al-P 及 Fe-P 型態存在，二者之比約為１：１。

2.施肥聚積磷素之回收率（以 Bray's P-1 法測定者）在 13.8% 至 62.2% 之間，十二土壤平均為35.5%。回收率之高低與土壤之 CEC, P Sorption 及 O. M. 含量成顯著負相關關係，而與有效磷含量成顯著正相關關係，如以土壤之 CEC, P Sorption 及 Bray's P 三者共同估計磷素回收率，其準確性可達78%。

3.作物磷吸收量與土壤 Bray 或 Olsen 磷均有極顯著之相關關係，其相關係數依次為 0.853** 及 0.866**；但與 EUF 法測得磷之相關關係則較差。以上結果顯示以 Bray 或 Olsen 法測得之土壤有效磷可有效代表土壤中可被作物吸收利用之磷含量，無論此磷肥係過去或新近施用者。又本研究資料顯示作物吸收之磷在原土壤中多為 Fe-P，施肥土壤中則多為 Al-P。

通常施於土壤中的磷肥僅５—25% 為當期作物所吸收，其餘均殘留土壤 (6,10,21)。磷為在土壤中不易移動的養分，受淋失的機會較少，因之連年施用後，必有多量磷肥殘留於土壤。

磷肥施於土壤後，在酸性土壤中多與 Al 及 Fe 結合；在礆性土壤中多與 Ca 結合而形成各種不同型態而溶解度低的磷化合物，即通常所謂「磷的固定」，意即固定的磷不易再被作物吸收利用。但事實上，在很多土壤中，此種「固定的磷」仍能大量供給作物所需的磷，而成為土壤中一大磷的資源。

據英國 Rothamsted 所作長期磷肥試驗的資料 (9)：在每年施用 22 lb P_2O_5/acre 的磷肥，連續施用 100 年後停施，而停施十二年時仍有明顯磷肥的殘效。

Ensminger (13) 在美國 Alabama 州所作磷肥殘效試驗顯示：當連續四年，每年施用 120、90、60 及 30 lb P_2O_5/acre 的磷肥，其後即停施，而於停施後十五年棉花產量仍與過去磷肥施用量成正比。

1.臺灣省農業試驗所　研究報告第1094號。

2.本所農化系副研究員。臺灣省　臺中縣　霧峰鄉。

另一在美國 North Carolina 州高磷固定力的 Georgeville 土壤中所作試驗也顯示磷肥施用九年後，仍有明顯殘效[10]。

由於能源問題的漸被重視，有關磷肥殘效的研究近年在歐美各國所作研究甚多[4,11,12,16,23]。本省在磷肥殘效方面之研究工作尚未開始，累積磷肥在不同土壤中的有效度及其施入土壤後的變化等均爲需待研究的問題。本研究的目的即在探知累積施用磷肥對土壤磷有效指數及施磷效應的影響及磷肥施入土壤後，在土壤中之結合型態及變化。又電透法（Electro-ultra-filtration）經 Nemeth[17] 改進後，已爲近年來許多國家競相研究的土壤有效養分測定方法，本研究中土壤有效磷含量的測定，也包括 EUF 法，以與其他慣用方法比較。

材料與方法

一、土壤：共十二種，採自全省各地包括多種土類，其有效磷含量由極低至極高。各土壤所屬之類別，母質及採取地點列於表 1 。（此等土壤係1968年採自全省，故在試驗前之十四年內未再施肥）。

表1. 試驗用土壤之土類、母質及其採取地點

Table 1. Soil group, parent material, and sampling location of the soils used

土號 Soil No.	土類 Soil group	母質 Parent material	採取地點 Sampling location
1	紅棕壤	洪積層	桃園中壢上青埔田27—7
2	冲積土	洪積層、砂頁岩、粘板岩混合	臺中淸水社口田79—148
3	冲積土	砂頁岩	臺中神崗大社田410
4	冲積土	粘板岩（新濁水溪冲積）	彰化埤頭周厝崙段379—303
5	臺灣粘土	砂頁岩	臺南新營王公廟電信大樓後
6	冲積土	砂頁岩	臺南六甲龜子港段129之9
7	風積土	砂頁岩	臺南市結核病院對面
8	冲積土	粘板岩新冲積土	屏東佳東田258
9	冲積土	南部砂頁岩	屏東恆春車城鄉新街圖298
10	冲積土		
11	東海岸冲積土	砂頁岩混合火成岩	臺東東河
12	黑土	火成岩	臺東長濱

二、土壤性質分析：

（一）一般性質：包括土壤 pH，有機質、陽離子交換能量，交換性 Ca、Mg、K，及機械分析等均依本省現行採用之方法[1]，全氮則以 Kjeldahl 氏法分解後，以 Sodium hypochlorite 法比色測定。交換性 Al 用 Coleman 氏法[7]，活性鐵用 Asami & Kumada 氏法[5]，本試驗所用土壤之一般性質列於表 2 。

（二）有效磷：共用三種方法測定。

1. Bray's p-1 法：以 0.025N $HCl-0.03N$ NH_4F 抽出。
2. Olsen氏法：以 pH 8.5, 0.5 M $NaHCO_3$ 抽出。
3. 電透法（Electro-ultra-filtration 或 EUF）：又分以室溫，200 V 抽取 30 分鐘之

Available P 及以 80°C, 400V 抽取5分鐘之 P reserve 兩部分 (17)。

（三）無機磷型態測定：用修正的 Chang & Jackson 氏法 (19)，唯各型態磷抽出後改以 L-ascorbic acid 法比色測定。本試驗中僅測定 Al-P, Fe-P 及 Ca-P 三種。

表 2. 試驗用土壤性質

Table 2. Some chemical properties of the soils used in this experiment

Soil No.	pH	O. M. %	Total N %	CEC	Exchangeable K (meq/100)	Exchangeable Ca (meq/100)	Exchangeable Mg (meq/100)	Ex. Al ppm	Free Fe_2O_3 %	% Clay	% Silt	% Sand	Texture
1	5.7	2.02	0.10	8.30	0.52	3.14	1.27	52	2.48	35.96	52.30	11.74	SiCL
2	6.7	2.78	0.16	12.84	0.14	5.75	3.89	0	1.17	19.96	56.30	23.74	SiL
3	5.1	2.17	0.12	7.67	0.31	2.97	1.27	238	0.58	21.96	56.30	21.74	SiL
4	6.0	2.02	0.11	4.50	0.12	3.29	1.30	0	1.54	11.96	32.30	55.74	SiL
5	8.2	2.39	0.13	18.87	0.45	10.97	6.48	0	2.17	39.96	54.30	5.74	SiCL
6	7.0	1.20	0.06	8.83	0.31	4.25	3.64	0	1.77	20.96	55.30	23.74	SiL
7	5.8	0.51	0.01	2.29	0.10	1.58	0.16	138	1.23	3.63	6.30	89.74	LS
8	7.5	3.22	0.25	14.31	0.17	10.98	5.26	0	1.89	31.96	58.30	9.74	SiCL
9	6.6	2.24	0.10	9.43	0.19	3.77	3.14	0	1.62	17.96	52.30	29.74	SiL
10	5.5	2.09	0.08	9.11	0.31	2.23	0.34	809	3.19	38.96	43.30	17.74	SiCL
11	5.9	4.41	0.15	28.36	0.43	12.22	8.63	11	1.11	25.18	53.94	20.88	SiL
12	5.8	4.41	0.16	32.36	0.41	13.77	12.46	0	1.32	33.18	39.94	26.88	CL

（四）磷吸着係數：稱土壤 2.5 克置於 50 ml 塑膠離心管中，加 25 ml 500 ppm P 溶液（溶於 0.01 M $CaCl_2$ 中），及甲苯二滴，以橡皮塞塞緊，置於搖動機上，搖動30分鐘後，置於 30 °C 之保溫箱內，保溫九天，每日取出予以搖動 30分鐘，九天後取出搖動 30 分鐘後，離心，取澄清液以鉬黃法比色，測定土壤吸着磷的量 (14)。

三、磷聚積處理：將多量磷肥，分數次加入土壤，並經乾濕處理，以摸擬田間情況。

（一）加磷處理：各土壤於風乾磨碎後，分盛於盆栽試盆中，每盆盛土三公斤，在土壤中先加入 $Ca(H_2PO_4)_2$ 200 ppm P，隨即浸水碎土，繼之任其風乾，乾後（約需一個月）再加入 100 ppm P，浸水碎土，風乾。如此再重複三次，共加入磷酸一鈣 500 ppm P。自 70年12月 9 日開始第一次加入磷肥浸水，至71年 5 月10日全部處理完畢，共歷時五個月。

（二）原土對照：各土壤均有一對照處理，除不施磷肥外，其他浸水，碎土，風乾等均與加磷處理者同時進行。

（三）前述經（一）、（二）處理過的土壤再進行有效磷、無機磷型態及磷吸着係數測定。

四、Neubauer 法磷效應試驗：稱乾土100克，加石英砂（經 3 N HCl 洗淨者）50克，置於直徑11公分高 7 公分之棕色玻璃皿中，加水潤濕，每盆加 75 mg $(NH_4)_2SO_4$ 及 60 mg KNO_3，磷肥則用 $Ca(H_2PO_4)_2$，分 P_0（不施），P_1（30ppm P），及 P_2（60 ppm P）三等級施入。土壤經壓平後，上舖石英砂100克，再加水潤濕，用特製之打孔板將上層濕砂打成分佈均勻之 91 孔，將小麥播於各孔中，壓實，上再舖石英砂50克。12種土壤× 2 種前處理× 3 等級磷處理× 4 重複，共計240盆，植於溫室。

五、作物磷吸收量測定：前述 Neubauer 試驗中種植之小麥，收割時從砂層表面剪下，經烘乾（75

—80°C）後記錄其重量，再經磨細，以濃硫酸及 H_2O_2 分解後，用鉬黃法測定其含磷量，再計算各土壤及各處理之磷吸收量。

結果與討論

一、原土壤中磷素與施肥磷素之聚積型態：

（一）原土壤中磷素之聚積型態：表3顯示原土壤（未施用磷肥土壤）中之磷幾乎全以 Fe-P 及 Ca-P 存在。前者在十二土壤中平均佔 53.2%；後者佔 44.8%，而以 Al-P 型態存在者僅佔三者總量之1.9%。

表3. 原土壤中磷素與施肥磷素之聚積型態

Table 3. Comparison of inorganic forms of soil P in soils with and without P accumulation treatment.

土 號 Soil No.	處 理 Treatment	Al-P		Fe-P		Ca-P		Total Al-P+Fe-P+Ca-P
		P ppm	%	P ppm	%	P ppm	%	
1	O	2.7	1.62	140	83.98	24	14.40	167
	P	342	86.28	134	26.59	28	5.56	504
2	O	1.8	0.58	230	74.92	75	24.43	307
	P	209	25.15	520	62.58	102	12.27	831
3	O	4.3	1.54	190	68.10	85	30.47	279
	P	442	52.49	300	35.63	100	11.88	842
4	O	4.1	1.45	68	24.11	210	74.47	282
	P	327	36.45	130	14.49	440	49.05	897
5	O	3.4	1.48	97	42.17	130	56.52	230
	P	247	38.00	300	46.15	103	15.85	650
6	O	3.4	3.95	60	69.77	22	25.58	86
	P	224	46.00	235	48.25	28	5.75	487
7	O	4.0	1.27	80	25.48	230	73.25	314
	P	280	42.42	160	24.24	220	33.33	660
8	O	3.7	1.69	55	25.11	160	73.01	219
	P	231	40.46	200	35.03	140	24.52	571
9	O	4.3	2.15	60	30.00	136	68.00	200
	P	180	25.42	390	55.08	138	19.49	708
10	O	4.5	4.02	77	68.75	30	26.79	112
	P	311	54.09	230	40.00	34	5.91	575
11	O	2.3	1.08	100	47.17	110	51.89	212
	P	225	30.00	330	50.67	145	19.33	750
12	O	1.9	1.51	100	79.37	24	19.05	126
	P	195	35.26	315	56.96	43	7.78	553
Average	O	3.4	1.86	105	53.20	103	44.83	211
	P	268	42.67	275	41.31	127	17.56	669

Peterson[19] 曾以美國 Wisconsin 州的各種不同土類，其中包括酸性土壤，作土壤中P-fractionation 測定，資料中也以 Al-P 所佔百分率最低，Fe-P 與 Ca-P 含量較高，唯 Al-P 與 Fe-P 及 Ca-P 間的差不若本試驗中土壤大。

張氏 [8] 也認爲任何土壤（新施磷肥者例外）中的磷以 Al-P 型態存在者必遠低於 Fe-P 及 Ca-P。

林氏 [3] 曾以本省主要土類作土壤樣本乾燥程度對於磷鉀有效指數的影響，試驗中也曾分析各土壤中不同型態磷，其風乾土壤中 Al-P 平均佔三者總量之 9.5%；Fe-P 佔 29.9%；Ca-P 佔 60.6%。

本試驗中未施磷肥處理之土壤所含 Al-P 平均僅佔三種型態磷的 1.9%，較前述研究資料所佔百分率均低，或係由於此等土壤在試驗前之十餘年中均未再行施用磷肥（所用土壤係1968年採自全省，此後即以大桶貯於本所網室中），而土壤中無機型態磷仍在繼續緩慢轉變中。

（二）施肥磷素之聚積型態：表 3 顯示經多量磷肥（500 ppm P）處理後之土壤中，大部分的磷係以 Al-P 型態存在，其次爲 Fe-P，而以 Ca-P 型態存在者極少。如以三者所佔百分率而言，則施磷處理後之土壤，Al-P 所佔的百分率躍居三者之首，而佔 42.8%（十二土壤平均值）；Ca-P 則由原土壤的 44.8% 減低爲 17.6%；Fe-P 由原佔的 53.2% 減爲 41.3%。

張氏[8] 在其對土壤有效磷化學之研究中，也發現磷肥施入土壤後，多被固定爲 Al-p，其後此 Al-P 即漸轉變爲 Fe-P 及 Ca-P。

Shelton 氏等[20] 之試驗資料也顯示施入土壤中的磷肥多以 Al-P 型態存在。

又據 Yost 等[23] 以 Central Brazil 的土壤所作之試驗資料顯示，施肥量低時（50 kg p/ha), Fe-P 高於 Al-P（由於 Fe 化合物較易與磷結合），但當施肥量高時(560 kg p/ha），初期 Al-P 含量也高於 Fe-P 及 Ca-P，其後 Al-P 即逐漸轉變爲 Fe-P。且施入土壤中之磷肥量愈高，其 Al-P/Fe-P 之比例即愈高，當施用量爲 856kg p/ha 時，施用12天後之 Al-P/Fe-P 比爲1.1，但施用30天後此比例即降低爲 0.75。30天以後的變化即很緩慢。

本試驗資料顯示施用磷肥 500 ppm P 或 1,250 kg p/ha 後土壤中的磷絕大部分（84%）呈 Al-P 及 Fe-P 型態存在，二者之比約爲 1：1。

二、施肥聚積磷素之回收率：

（一）磷素之回收率：此處所稱之回收率係指經施用 $Ca(H_2PO_4)_2$ 500 ppm P 處理後之土壤以化學測定法測得有效磷增加量所佔原施入量的百分率。

表 4 爲各土壤未經施磷及施用磷肥 500 ppm P 後有效磷含量（Bray's p-1 及Olsen 氏兩法測値）及各土壤之磷肥回收率。

以 Bray's p-1 法測得之有效磷回收率在 13.8至 62.2% 之間，平均爲 35.5%；以 Olsen 氏法測得者回收率在12.2%至62.4%之間，平均爲32.5%，兩法之平均極爲接近。如以 Bray's p-1 法測值而言，磷回收率自 13.8% 至 62.2%，也即欲提高土壤有效磷 1 ppm，需施磷肥 2 至 7 ppm，或平均提高有效磷測值 1 ppm，需施用磷肥 3 ppm。Peck[18] 氏等曾以田間試驗及實驗室保溫（22 °C）培養試驗探求施用磷肥後 Bray's p-1 土壤磷測定值的變化，其田間試驗結果爲欲提高磷測定值 1 ppm，需施用磷 4 ppm；其保溫培養所用土壤種類較多，保溫期間爲 49 星期，結果爲欲提高 Bray's p-1 磷測值 1 ppm，需施用磷 2-10 ppm，該試驗中保溫培養所用土壤爲過去未施用過磷肥者，試驗進行時磷肥施用後，土壤保溫期間，曾於不同期間取出土壤，以 Bray's p-1 法測定其有

表 4. 試驗用土壤之磷素回收率及磷吸着係數

Table 4. P recovery rate and P sorption of the experimental soils

土 號 Soil No.	處 理 Treatment	Bray's P P ppm	Bray's P Recovery rate %	Olsen's P P ppm	Olsen's P Recovery rate %	P Sorption P_2O_5 mg/100g soil
1	O	16	40.8*	6	30.0	381
	P	220		156		295
2	O	32	25.6	21	19.8	497
	P	160		120		375
3	O	65	61.0	40	62.4	206
	P	370		352		135
4	O	29	62.2	13	32.6	140
	P	340		176		72
5	O	16	26.8	10	34.6	551
	P	150		183		452
6	O	8	37.4	3	30.0	251
	P	195		153		188
7	O	62	49.6	27	45.8	271
	P	310		256		197
8	O	11	31.8	4	35.2	450
	P	170		180		443
9	O	7	23.6	7	12.2	272
	P	125		68		268
10	O	17	38.6	5	33.0	461
	P	210		170		438
11	O	8	13.8	10	24.0	409
	P	77		130		402
1	O	7	14.8	7	29.8	410
	P	81		156		436
Average	O	18	35.5	13	32.5	358
	P	201		175		308

* $\frac{220-16}{500} \times 100 - 40.8\%$

效磷的變化，直至49星期爲止，各土壤測定值的變化在16星期後幾乎均已穩定。

Griffin & Hanna[15] 爲求美國 New Jersy 土壤磷肥的 "Fertilizer equivalent"，將磷肥加入土壤後保溫 6 星期，所得結果爲使 Bray's p-1 測值提高 0.45 kg 需施磷 0.8 至 2.1 kg。

本試驗中磷聚積處理自開始至結束共歷時五個月，其有效磷測值應已趨穩定，所得結果與前述 Peck 及 Griffin 者也極接近。

（二）磷素回收率與土壤性質之關係：本試驗中所用12種土壤施用磷肥後之回收率相差很多，其中最低者為東部之東河及長濱兩土壤（土號11及12），回收率僅 14%（Bray's p-1 法測值）；回收率最高之土壤為彰化之新濁水系冲積土（土號4），達62%，兩者間相差幾達五倍，而土壤性質相差也很多。

經將土壤性質中可能影響磷回收率之 pH, O. M., CEC, Ex. Ca, Al, Free Fe, P sorption, Bray's p, Al-P, Fe-P, Ca-P, Clay 及 Clay+Silt 等十三項與磷回收率作迴歸分析，發現其中五項與磷回收率達顯著或極顯著之關係，其單相關係數如表 5。

表 5. 磷素回收率與土壤性質之相關關係

Table 5. Correlation coefficients for relationships between P recovery rate and soil characteristics

	O. M.	CEC	Ex. Ca	P sorption	Bray's p
P recovery rate	−0.684*	−0.780**	−0.727**	−0.677*	0.706*

* Significant at 5% level, **Significant at 1% level.

上表顯示 O. M., Ex. Ca 含量高，CEC 及 P Sorption 大的土壤施磷肥後被固定的機會較多；Bray 磷含量較高的土壤被固定的機會較低。其中除 CEC 一項外，均甚為合理。粘土礦物中之高嶺石類較蒙特石類固磷較多 [6]，但前者之 CEC 遠低於後者，此點似與本試驗結果矛盾，係因本試驗所用土壤無含蒙特石類粘土礦物之故。

又複迴歸分析結果，發現如以土壤 CEC, P sorption 及 Bray's p 三者估計磷回收率，其可靠性可達78%，如圖 1。

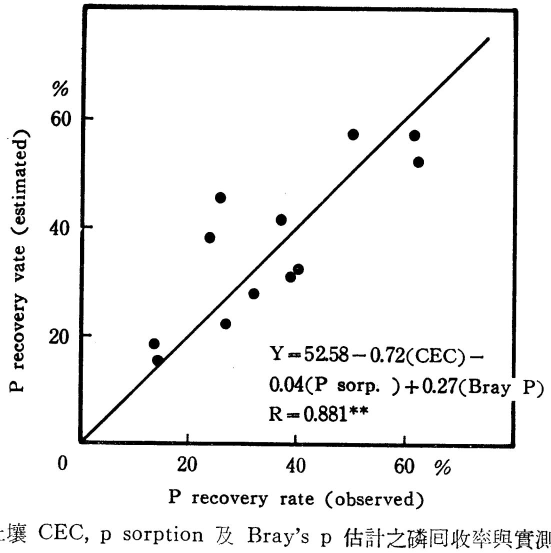

圖1. 以土壤 CEC, p sorption 及 Bray's p 估計之磷回收率與實測值之關係

Fig. 1. Relationship between P recovery rate estimated by soil CEC, P sorption as well as Bray's P and observed P recovery rate

三、作物磷吸收量與土壤有效磷測值及磷型態之關係：

本研究中曾以經磷聚積處理過的土壤及各土壤的對照處理進行 Neubauer 法磷效應試驗兩次。第一次爲71年5月10日播種，5月21日收割；第二次爲6月1日播種，6月17日收割，兩次各土壤均有三等級磷肥處理，但小麥收量在不同磷等級處理間無差異，因之無法找出累積施用磷肥後磷缺乏臨界值有無改變。

表6. 小麥磷吸收量及磷含量與土壤性質之關係 [a]

Table 6. Correlation coefficients for relationships between soil characteristics and P uptake by wheat

Soil factors	P % (in plant)	P uptake
pH	0.001	−0.429
O. M.	−0.191	0.030
CEC	−0.246	−0.163
Ex. Ca	−0.201	−0.304
Ex. Al	−0.345	0.010
Free Fe	−0.416	−0.418
P sorption	0.115	−0.053
Bray's P	0.503	0.499
Al-P	−0.397	−0.324
Fe-P	0.691**	0.941**
Ca-P	0.223	−0.201
Clay	−0.402	−0.178
Clay+silt	−0.295	0.026

* Significant at 5% level, **Significant at 1% level.

a. 本表中僅包括無磷聚積之土壤。

本報告中之作物產量及磷吸收量，磷含量資料均係以經磷聚積處理過的土壤（12種土壤× $\left\{\begin{matrix}P_0\\P\end{matrix}\right.$兩處理）而在種小麥前未再施磷的處理計算（兩次各四重複計八盆資料之平均）（表7）。

（一）土壤性質與作物磷吸收量及磷含量的關係：

作物磷吸收量與土壤性質應有密切關係。經將土壤性質中可能與磷吸收量有關之若干性質（其中 P sorption, Bray's p , Al-P, Fe-P 及 Ca-P 等均採用未施磷處理之資料）與磷吸收量（無磷聚積處理者）作單相關迴歸分析，結果列於表6。此表顯示土壤性質中僅 Fe-P 的含量與小麥磷吸收量及含量關係達顯著程度，與其他土壤性質關係均不顯著。

本試驗中所用土壤之磷型態（表3未施磷肥者）有 53.2%爲 Fe-P，故作物吸收者多爲 Fe-P，但 Ca-P 也佔 44.8%，而其與作物磷吸收量及含量之關係却遠遜於 Fe-P，應係由於 Ca-P 較 Fe-P 更不易被作物吸收之故。

（二）作物磷吸收量及含量與土壤有效磷測定方法之關係：

表7所列資料爲以不同有效磷測定法測出之原土壤及加磷處理過之土壤中有效磷含量及小麥磷含量，磷吸收量。表8爲其間之單相關關係（包括有與無磷聚積之土壤）。

表7. 原土壤與磷素聚積土壤中有效磷含量及作物磷吸收量

Table 7. Quantities of P extracted by different methods from samples with and without P accumulation treatment and P uptake by wheat

土 號 Soil No.	處 理 Treatment	Bray's P P ppm	Olsen's P P ppm	EUF-P (ug/5g Soil)			P% (in wheat)	P uptake by wheat (mg/pot)
				30min.	5min.	Total		
1	O	16	6	1.1	1.2	2.3	0.56	1.68
	P	220	156	76	91	167	0.81	4.81
2	O	32	21	39	26	65	0.64	2.88
	P	160	120	147	139	286	0.83	5.54
3	O	65	40	26	12	38	0.53	2.30
	P	370	352	185	274	459	0.87	8.70
4	O	29	13	52	10	62	0.50	0.93
	P	340	176	212	215	427	0.85	6.24
5	O	16	10	7	2	9	0.52	0.19
	P	150	183	122	42	164	0.72	3.90
6	O	8	3	0	0.5	0.5	0.48	0.17
	P	195	153	203	107	310	0.74	3.65
7	P	62	27	107	125	232	0.59	0.68
	O	310	256	453	430	883	0.87	4.70
8	O	11	4	36	4	40	0.50	0.16
	P	170	180	163	45	208	0.73	2.27
9	O	7	7	13	9	22	0.51	0.66
	P	125	68	88	84	172	0.72	3.40
10	O	17	5	1	0.6	1.6	0.45	0.54
	P	210	170	45	56	101	0.67	2.86
11	O	8	10	11	6	17	0.51	0.76
	P	77	130	83	60	143	0.73	5.10
12	O	7	7	3	3	6	0.49	0.75
	P	81	156	84	53	137	0.70	3.47
Average	O	18	13	25	17	41	0.52	0.98
	P	201	175	155	133	288	0.77	4.55

表8. 作物磷吸收量及磷含量與土壤有效磷測值及磷型態之相關關係

Table 8. Correlation coefficients for relationships between plant P uptake, P content in plant and soil available P as well as inorganic forms of soil P

	Olsen's P	EUF-P (30min)	EUF-P (5min)	EUF-P (Total)	Al-P	Fe-P	Ca-P	P%(in plant)	P uptake
Bray's P	0.919**	0.789**	0.832**	0.826**	0.922**	0.368	0.355	0.895**	0.858**
Olsen's P		0.715**	0.757**	0.769**	0.944**	0.495*	0.162	0.882**	0.866**
EUF-P (200V, 30 min.)			0.922**	0.980**	0.647**	0.284	0.454*	0.781**	0.621**
EUF-P (400V, 5min.)				0.980**	0.665**	0.255	0.450*	0.777**	0.700**
EUF-P (Total)					0.669**	0.275	0.461*	0.795**	0.674**
Al-P						0.537**	0.164	0.911**	0.883**
Fe-P							−0.117	0.630**	0.667**
Ca-P								0.289	0.216

*Significant at 5% level, **Significant at 1% level.

由表8知以 Bray, Olsen 及 EUF 三種方法抽出之磷與作物磷吸收量及含量之相關關係中，Bray 氏法與 Olsen 氏法極為接近，而 EUF 法較低。以 EUF 法抽取之磷無論以 200 V，室溫30分鐘或 400 V, 80 °C 抽取5分鐘或兩者相加之量與植物磷吸收量之關係均遜於前二法者，雖其相關係數均已達1%顯著平準。

表8中相關分析資料係包括經加磷及未加磷處理之土壤。由作物磷吸收量與土壤 Bray 及 Olsen 磷的極顯著相關關係（圖2及3）知以此二法測得之土壤有效磷已可有效代表土壤中可被作物吸收利用之磷含量，無論此磷肥係過去或新近施用者。圖4及5為小麥磷含量與 Bray 及 Olsen 磷之曲線相關關係，較直線關係更為密切。

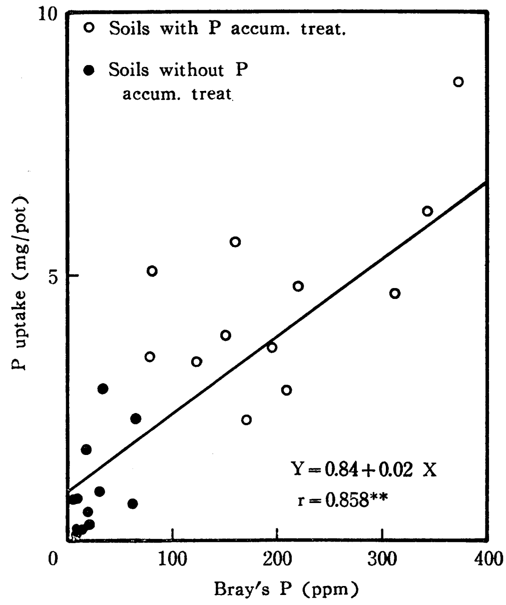

圖2. Bray 磷與作物磷吸收量的關係
Fig. 2. Relationship between Bray's P and P uptake by plant.

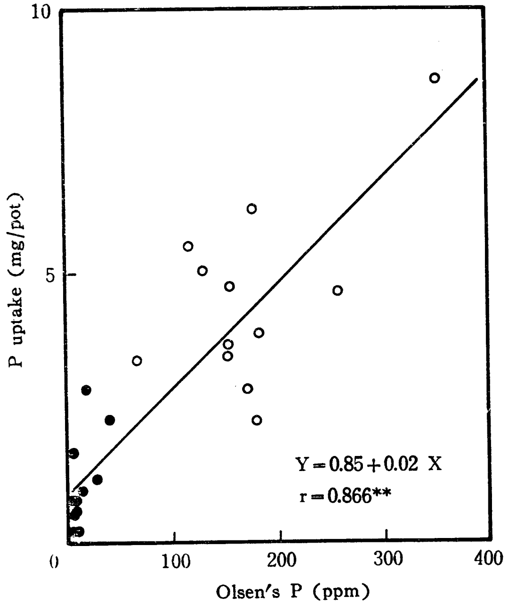

圖3. Olsen 磷與作物磷吸收量的關係
Fig. 3. Relationship between Olsen's P and P uptake by plant.

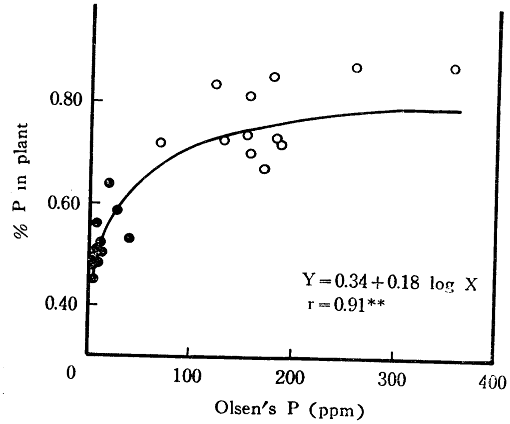

圖4. Olsen 磷與作物磷含量的關係
Fig. 4. Relationship between Olsen's P and P content in plant.

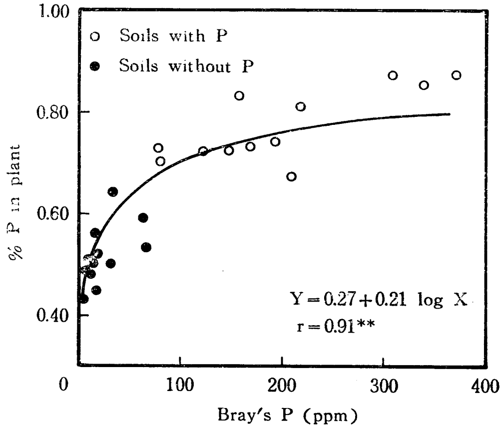

圖5. Bray 磷與作物磷含量的關係
Fig. 5. Relationship between Bray's P and P content in plant.

Yost[23] 也認爲土壤中可抽取性磷（該研究中係以 0.05 N HCl+0.025 N H_2SO_4 抽取者）可有效代表土壤中過去或現在施用磷肥之有效度。但 Adepoju 及 Pratt[4] 等對已有多量磷肥殘留之土壤所作之研究資料則顯示可被作物吸收利用的磷無法全賴化學抽取法之測値決定，而必須同時考慮土壤性質。

（三）作物磷吸收量及含量與土壤中磷型態之關係：

表 8 顯示作物磷吸收量及含量與三型態磷中之 Al-P 關係最密切，Fe-P 居次，Ca-P 最差。表 6 之資料則顯示作物磷吸收量與 Fe-P 含量之關係最密切。足見在新近施用磷肥之土壤中，Al-P 之含量仍高，則作物吸收者以 Al-P 最多，Fe-P 居次。當 Al-P 在土壤中逐漸轉變爲 Fe-P 及 Ca-P 後，作物吸收者即以 Fe-P 爲主。

張氏[8] 在其早年對水稻所作之試驗中，發現水稻所吸收之磷係以 Fe-P 爲主，其次爲 Al-P。林氏[2] 以玉米所作的試驗中則發現在旱作情形下，玉米吸收的磷以 Al-P 爲主，其次爲 Fe-P。蔡氏[22] 以菸草所作之試驗，也認爲菸草吸收的磷與土壤中的 Al-P 相關顯著，而與 Fe-P 及 Ca-P 則否。

又 Bray 氏及 Olsen 氏法抽取之磷也與 Al-P 之相關最高（相關係數依次爲0.922**及0.944**）。此項結果與 Shelton 等[20] 所得結果也極相符。彼等發現以 0.05 N HCl+0.025 N H_2SO_4 抽取之土壤有效磷與 Al-P 有密切的關係。

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The Accumulation, Transformation, and Utilization of Phosphorus Fertilizer Applied in Different Soils[1] under Upland Condition

Lee Tze-Shun[2]

Summary

Phosphorus was incorporated into 12 different soils in 4 successive applications at 30 days interval in the greenhouse. After each addition, the soils were submerged for 10 days, than left until dry to simulate field conditions. A total of 500 ppm P was applied while a check treatment (no P was added) was included for each soil. After this pre-treatment, the soils were used for Neubauer's P test ; the plants grown were wheat. Soil chemical properties were analyzed and available P was extracted by Bray's, Olsen's, and EUF methods. Distribution of inorganic P fractions were determined for both the P-treated and check soils. This study was conducted to compare the distribution of inorganic P fractions in the original soil and P-enriched soil, the extractability and availability of P applied in soil as well as the P recovery rate of these soils.

The results are summarized as follows.

1. P fractionation data show that in the original soil, the inorganic P forms are dominantly Fe-P (53.2%) and Ca-P (44.8%), and only 1.9% is Al-P (the average of 12 soils), whereas in the P-fertilized soil, 84% of the inorganic P fractions are Al-P and Fe-P, with a ratio of about 1 : 1, and Ca-P becomes the minor part.

2. The P recovery rate (as determined by Bray's P-1 method) of the 12 soils varies greatly from 13.8 to 62.2%, with an average of 35.5%. regression study shows that P recovery rate is negatively correlated with soil CEC, P sorption, and O. M. content, but positively correlated with soil available P. When P recovery rate is estimated by soil CEC, P sorption and Bray's P together (the multiple corrlation coefficient R=0.881**), its accuracy is 78%.

3. Quantities of soil P extracted by Bray's, Olsen's, and EUF methods are significantly correlated with plant P uptake, while the Bray's and Olsen's methods producing the higher correlation coefficients (0.858** and 0.866** respectively) . This significant correlation signifies that soil available P as extracted by Bray's or Olsen's method can effectively represent the amount of P in soil that can be utilized by plants, no matter it is newly applied or not.

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1. Contribution No. 1094 from the Taiwan Agricultural Research Institute.
2. Soil Chemist, Department of Agricultural Chemistry, TARI, Wufeng, Taichung Hsien, Taiwan, 431, ROC.

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長期連用矽酸爐渣對水稻收量和土壤化學性質之影響[1]

連　深　　王鐘和[2]

摘要：本研究綜合檢討９處矽酸爐渣連用試驗經歷５年（10作）及１處矽酸爐渣、稻藁連用試驗歷經６½年（13作水稻）之收量結果，並分析矽酸爐渣之連用對土壤化學性質之影響。

試驗地點分佈西部各縣、土壤均屬酸性。９處矽酸爐渣連用試驗之處理爲（１）對照區；不施矽酸爐渣，（２）矽酸爐渣每期作每公頃 1.5 公噸，（３）矽酸爐渣每期作每公頃３公噸，但自第７作（69年第二期作）起將（２）及（３）處理各分爲二半，一半繼續施用矽酸爐渣（照原量），另一半則停施以觀矽酸爐渣之殘效及續施效果。另一處矽酸爐渣，稻藁連用試驗則以稻藁之掩埋與否（即稻藁每期作每公頃０及５公噸）爲主處理，矽酸爐渣之施用與否（即爐渣每期作每公頃０及２公噸）爲副處理，亦自第７作起以試驗田之一半停施矽酸爐渣以觀殘效。以上試驗各處理區，均依標準施肥法施用足量之三要素肥料。結果如下：

1.矽酸爐渣之肥效除了其施用初期略低外，其餘歷作平均增收率爐渣 1.5 及３噸區各爲５～15及８～20%，此種矽酸爐渣肥效之不同年度變異主要係與對照區之收量有關（成負相關），而與爐渣連用年數之累加無關。即爐渣之連用雖達９～12作，尙看不出爐渣之肥效有任何隨著連用年數之增加而增加或降低之顯著趨勢。

2.連用矽酸爐渣之稻田對其次作水稻常有顯著的殘效，但隨著停施時間之經過殘效却有顯著降低趨勢；爐渣連６作用後其在土壤中之累積用量已甚可觀，但在第７作其停施之效果即甚顯然，亦即在第７作所表現之殘效已顯著低於續施之效果。矽酸爐渣連用 10 作期間，其1.5公噸區和３公噸區之增產效果亦始終維持一定差距，即無論連用年數之增加始終以３公噸區之效果較大。

3.矽酸爐渣每公頃每作連用1.5及３公噸，於第７ 作後表土 pH 值平均各約提高 0.4及 0.8單位，有效矽含量平均各約提高 130 及 300 ppm。繼續施用爐渣並無繼續顯著提高土壤 pH 值及有效矽含量趨勢，惟其停施後之降低却甚明顯；矽酸爐渣連用６作後其土壤中之矽酸累積用量已甚可觀，但爐渣在第７作時停施却使土壤中之有效矽酸含量顯著降低，土壤中之可還元性錳含量亦有同樣跡象。以上結果在稻體中亦有同樣反映。

由土壤中有效矽之投入量，水稻之吸收量及土壤中殘留之有效矽量等收支估計可以推測所施有效矽量之約 60%，已在土壤中被固定或吸着，變爲不易被 pH 4.0 的規定１N溶液萃取的形態。

由以上結果可見矽酸爐渣之增產效果非常顯著。迄第10～13作爲止矽酸爐渣之連用雖沒有繼續增高其增產效果趨勢，惟一旦停止施用其增產效果却會顯著減低，故爲維持較高之土壤肥力水準，矽酸爐渣之繼續施用可謂必要，並以每次施用量較少但繼續施用者較一次施用多量，但停施甚久者有效。實用上，缺矽的稻田，如能於每年第一期作繼續施用，每公頃約 1.5～２公噸矽酸爐渣將甚適當。

1.臺灣省農業試驗所　研究報告第1095號。本研究承70農建5.1產24號（Ⅲ）及 71 MCAC 產03號（丙）計畫補助，謹誌謝忱。又本研究中各田間試驗區的設置係農業發展委員會蘇技正楠榮博士所策劃，並承高雄、臺南、臺中、桃園區農業改良場副研究員鄭榮賢、黃和炎、黃山內、曾潤錦、呂文通，助理研究員陳富英、施宗禮、黃祥慶、彭達民、蘇春濤、莊能雄，諸位先生提供各試驗區收量資料，本所李主任蘭帝指導X光螢光分光分析，一併誌謝。

2.本所農化系研究員及助理。臺灣省　臺中縣　霧峰鄉。

由過去的許多試驗研究已知本省稻田土壤普遍缺乏植物可利用的有效態矽酸，而矽酸爐渣在低矽土壤之肥效非常顯著[1]。矽酸爐渣在低矽土壤之肥效甚至於超過磷肥或鉀肥之肥效；據民國 67～69 年第一期作全省共計一萬三千公頃低矽稻田的矽酸爐渣示範（每公頃施用 2 公噸）結果，爐渣施用區較對照區每公頃平均增產稻谷 608 公斤，增產率達12%，其中桃園紅壤稻田的增產率顯然較高，平均在 15～18%。[2,3,4] 矽酸爐渣肥效之主要原因在其矽酸之供給，蓋矽酸爐渣之肥效與被施土壤之有效矽含量有顯著的負相關；施用相當於爐渣中鈣含量的碳酸鈣肥效並不顯著[5,6]；土壤中直接施用矽膠之肥效甚至於超過矽酸爐渣的肥效。又據分析全省 120 處代表性稻田的水稻收量與各種土壤性質和水稻營養性狀的相關亦示收量與土壤中之有效矽含量和水稻植物體之矽含有率關係最為密切[7]。水稻胡麻葉枯病頻發土壤的肥力因子研究亦證明缺矽為其主要而普遍的低產及導病因子，並確認矽酸爐渣的顯著肥效[8]。另據全省5730個代表性土壤樣本的有效態 SiO_2 含量測定結果，有70%樣本的含量在 90 ppm 以下，45% 在 40 ppm 以下[9]。按依據本省過去的試驗結果，土壤中的有效態 SiO_2 含量在 40 ppm 以下者屬嚴重缺矽，40～90 ppm 者亦屬低矽的土壤[10]。可見臺灣土壤的缺矽情形相當普遍，稻田生產力與土壤有效態矽酸供應能力之密切關連及矽酸施肥之重要性。

又隨著本省工業之起飛，中鋼公司將有更大量之矽酸爐渣供應；其年產量俟本年度其二號高爐開始運轉已將高達 104 萬公噸。此等爐渣除一部分可以處理後供水泥及玻璃業使用外，餘均將廢棄，預料此種物料在稻田之施用將會更加普及，在同一稻田連續施用之機會亦會增多。

惟矽酸爐渣之化學成分除了矽酸鈣為主外，尚含多量鋁及少量鈦、鉻、鎳、硒等元素。因其施用量大，連年施用後在土壤中是否會有相當的累積而影響作物收量及品質？又即使矽酸爐渣對稻田收量之增產效果顯著，有否屢次施用必要？換言之，其停施後之殘效如何？又稻田中之矽酸爐渣之連用對其冬季裡（旱）作或稻田轉作旱作物時之影響如何？等問題乃吾人所關心者。

有關矽酸爐渣連用之問題，由於日本稻田施用爐渣之歷史較久，其試驗結果應可借鏡。惟日本水稻年僅一作，稻田之冬季裏（旱）作較少，有關試驗資料亦尚不多見。太田氏曾以電氣銑鐵爐渣和製燐爐渣舉辦連用試驗一處，以每公頃每作 1.1 公噸比率施用於夏作（水稻）和冬作（大麥），惟歷 5 年（共 10 作）後因田間試驗不能繼續，改為盆栽試驗。據其結果迄第 15 作為止爐渣區之收量指數為 147～163，但第17作以後其收量指數急激減為 74～76[11]。可見爐渣連用多年後亦可能轉為負效果，惜此項結果因泰半係盆栽試驗，未必能眞正反應田間實際情況。另據報告[12]日本九州農試場之直播水稻矽酸與微量元素試驗連用矽酸爐渣 4 年，原土 pH 5.7 因施用爐渣後已提高至 7.0 左右，且有效性矽酸含量亦不低，續施爐渣却仍有效果。又據報告[13]施過爐渣的土壤其有效態矽酸含量之測定方法與未施過爐渣的土壤的測定方法不同。凡此均示爐渣之繼續施用有效，但確切情形尚待究明。

為探討以上諸問題，第一步乃綜合考察兩項矽酸爐渣長期連用試驗計10處試驗地歷經10～13作之水稻收量成績，並分析土壤化學性質之變化情形。

材 料 及 方 法

1. 試驗地點及其表土之化學性質如表1.

2. 試驗設計

試驗一：

在莊圍、樹林、中壢、龍潭、后里、埔里、民雄、後壁、高樹及屏東市共十處進行。龍潭一處因缺水自民國69年 2 期以後停辦，故所有期作之資料均不加入收量平均之考察。又後壁一處民國69年 2 期亦因缺水未插秧，資料從缺。試驗設計如下：

自66年 2 期至69年 1 期：3 處理 2 重覆，隨機區集排列，小區面積 100 平方公尺（若干試地為50平方公尺）。處理㈠、不施矽酸爐渣，處理㈡、施矽酸爐渣1.5公噸／公頃，處理㈢、施矽酸爐渣3.0公噸／公頃。

表1. 各試驗地點土壤的一般理化性及肥力情況

Table 1. General properties and fertility status of the soils on each experimental locations.

Locations	Parent material	Texture	pH	OM%	CEC (me/100g)	Exch. (me/100g)			Easily Reducible Mn (ppm)	Available SiO_2 (ppm)
						Ca	Mg	K		
宜蘭 壯圍	粘板岩	SiL	5.1	2.5	5.2	2.8	0.8	0.08	21	39
臺北 樹林	{砂頁岩 粘板岩	SiL	4.9	2.3	6.5	3.4	1.1	0.06	5	34
桃園 中壢 (月眉)	紅 壤	SiL	5.3	3.2	7.6	2.2	0.8	0.13	8	72
桃園 中壢 (大崙)	紅 壤	SiL	5.5	2.9	9.3	3.3	0.8	0.13	15	75
臺中 后里	{粘板岩 紅 壤	L	5.4	2.5	6.0	3.5	0.9	0.05	4	36
南投 埔里	{砂頁岩 粘板岩	SiL	4.8	4.2	6.9	1.5	0.3	0.04	2	21
嘉義 民雄	砂頁岩	SiL	4.8	1.4	3.8	1.9	0.2	0.07	5	10
臺南 後壁	砂頁岩	CL	6.0	2.0	11.8	6.9	2.4	0.18	172	108
屏東 鼓樹	粘板岩	SiL	4.9	3.9	5.8	4.2	0.9	0.11	2	68
屏 東 市	粘板岩	SiL	5.8	2.6	9.9	8.4	1.2	0.08	16	69

自69年2期以後：將矽酸爐渣1.5公噸與3公噸區各劃分爲二半，一半繼續施用矽酸爐渣（照原來用量），另一半不施，以觀續施之效果及停施後之殘效。

試驗二：

在中壢（月眉里）進行。試驗設計爲裂區；以稻藁之掩埋與否（即稻藁每期作5及0公噸／公頃）爲主區，設二重覆。各主區內設矽酸爐渣之施用與否（即爐渣每期作2及0公噸／公頃）之副區（並聯）各三重覆，副區（即小區）面積爲10平方公尺。試驗自民國65年第1期作開始。自第7作（即民國68年第1期作）起亦以試驗田之一半（即兩個主區重覆之一）停施矽酸爐渣以觀殘效。

3.栽培品種：

各試驗地各使用開始試驗時之當地推廣品種，故包括臺農67號、臺南5號、高雄139號等，但以臺農67號爲主。

4.栽培管理方法：

各區均依標準施肥方法施用同量而且適量之三要素肥料。

5.調查研究項目：

（1）矽酸爐渣化學成分分析：

定性分析：在定量分析之前，先以爐渣樣本與纖維粉混合，以高壓壓成餅後，經X光螢光分光儀定性測定所存在之各種元素。

各種元素之全含量測定：爐渣樣本經過 Ball mill 磨細後依照 Jackson[14] 氏方法經氟酸和過氯酸處理製成溶液後測定鉀、鈣、鎂、鐵、錳、鈦、鋅、銅、鉻、鎳等元素含量。另經加碳酸鈉熔煸製成溶液後測定矽酸含量。

又另秤爐渣樣本2克，經王水（HNO_3 • HCl）溶解，分離矽酸後以原子吸光儀測定硒含量。

0.5 N 鹽酸可溶性含量之測定：以原廠樣本（即不再磨細），依照日本公定法[15]測定爐渣之可溶性矽酸含量，亦以所抽出之溶液測定其他各種要素含量。

（2）各試區稻谷收量。

（3）土壤分析：

於69年2期～70年2期各期水稻收穫後自各試區採取表（0～15 cm），底（15～30 cm）土分析一般理化性質，包括 pH、有機質、有效態磷、鉀及矽，陽離子交換能量及交換性鈣、鎂、鉀以及游離鐵和易還元性錳等含量。有效態矽之測定法根據 Imaizumi and Yoshida[16] 係以 pH 4.0 1N 醋酸鈉萃取，其他項目之測定則均依照 Black 氏所編土壤分析法[17]。

另以69年2期水稻收穫後自埔里對照區和爐渣 3 t/ha/crop 連用區所採土壤測定置換酸度[18]。另以各區土壤450公克，經 0.01 N HCl 淋洗至洗液之 pH 降至2為止，再經純水淋洗至洗液無 Cl^- 反應。測定總洗液之鈣、矽及鋁含量，及殘餘土壤之置換性鋁含量[17]。

（4）植物分析：於水稻生育期間及收穫期採取部份試地之水稻樣本測定各種要素含量。

結 果 及 討 論

1.爐渣之化學成分：

本試驗所施用之若干矽酸爐渣經分析全化學成分及 0.5 N 鹽酸可溶性成分，結果如表2.

表 2. 施用矽酸爐渣之化學成分（民國69—70年，爐渣來源：中鋼公司）

Table 2. Chemical composition of the slag applied in the experiment.

Total (%)

SiO_2	CaO	MgO	FeO	MnO	Al_2O_3	TiO_2	K_2O	P_2O_5	Ni	Cr	Zn	Cu	Se
34.6 ±1.2	39.2 ±2.3	7.3 ±0.4	0.45 ±0.19	0.33 ±0.02	17.1 ±1.7	0.53 ±0.03	0.66 ± 0.07	Nil	0.008 ±0.003	0.007 ±0.004	0.008	0.007	0.016

N/2 HCl soluble (%)

SiO_2	CaO	MgO	FeO	MnO	Al_2O_3	TiO_2	K_2O	Zn
21.6 ±2.2	23.9 ±3.0	4.9 ±0.8	0.31 ±0.09	0.28 ±0.02	9.7 ±1.4	0.15 ±0.01	0.48 >0.02	0.0002

Mean with standard error. Number of samples analyzed for N/2 HCl soluble SiO_2 were 10, while those analyzed for the other items were 4.

本試驗所施用爐渣66年第2期作係臺灣煉鐵公司所產，但自67年起均用中鋼公司所產者。

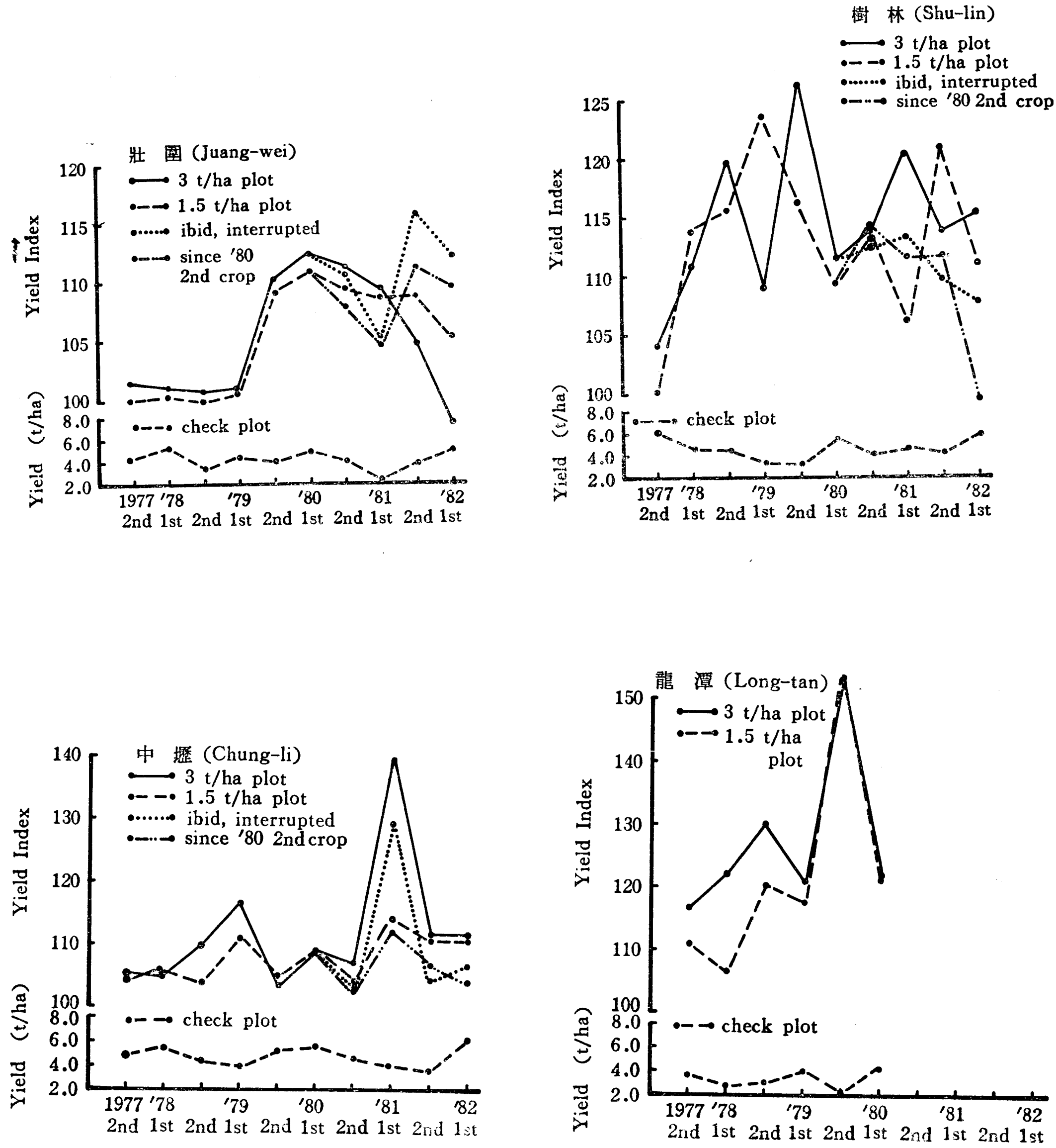
由表2可見矽酸爐渣之化學成分以矽酸鈣及鋁為主，尚含少量鐵、錳、鈦及微量、鉻、鎳、硒、鉬等元素。日本公定矽酸質肥料規格[19]規定其機械組成需全部通過 10 mesh (2 mm) 篩，60%以上通過 30 mesh (0.59 mm) 篩。其 0.5 N 鹽酸可溶性 SiO_2 含量須大於 20%，而其鈣及鎂含量以CaO 表示須大於 35%。其鎳、鉻、鈦等元素含量則應各小於0.60，6.0及3.0%。由表1所示成分看來所施用之爐渣都能符合上述規格。其機械組成測定結果粒徑分佈為 <50 mesh (0.25 mm) 者，50～20 mesh (0.25～0.50 mm) 者，20～10 mesh (0.50～2 mm) 者各佔全部之66，26及8%

，即可全部通過 10 mesh 篩，符合上述規格。

本試驗另經X光螢光分光儀測得爐渣中含有微量硒元素，乃經原子吸光儀測得其含量約爲 160 ppm，其對作物之影響尙待進一步研究。

2.矽酸爐渣長期連用對水稻收量之效果：

試驗一，十處試驗地（壯圍、樹林、中壢、龍潭、后里、埔里、民雄、後壁、高樹及屏東）歷作對照區之稻谷收量及矽酸爐渣1.5 及 3 公噸各連用區較對照區之增產百分率（收量指數）如圖 1，實驗部份所示。



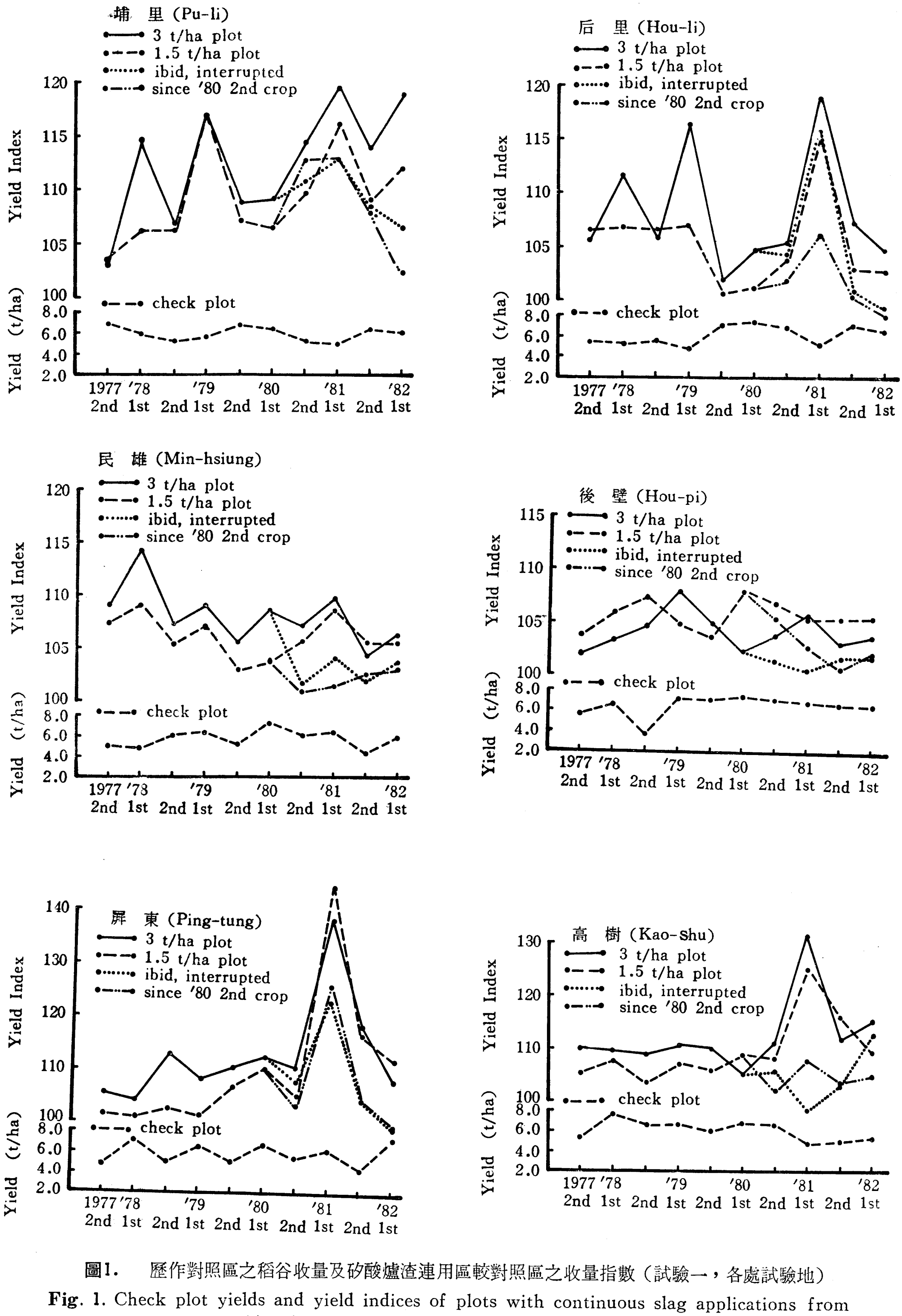


圖1. 歷作對照區之稻谷收量及矽酸爐渣連用區較對照區之收量指數（試驗一，各處試驗地）

Fig. 1. Check plot yields and yield indices of plots with continuous slag applications from 1977—1981. Yield index=(yield of plot with slag application/check plot yield)×100 (Experiment 1, individual location).

由圖1可見各處試驗地及不同的年度均示矽酸爐渣之增產效果，惟效果之變異幅度很大。乍看，這種變異並無規則，惟仔細觀察則可見無論是同一年度、期作之不同地點矽酸爐渣效應之變懷或各別地點之不同年度矽酸爐渣效應之變異均各與其對照區收量成負相關（表3及4）。可見決定爐渣效應之因素主要爲地點和年度；前者與土壤的肥力有關，後者則可能與氣象、病蟲害之發生等因素有關。尙難看出矽酸爐渣之肥效有任何隨著其連用年數之累加而增加或降低的明顯趨勢。

表3. 不同試驗地點之矽酸爐渣連用區收量指數（1）與各地點對照區收量之直線相關（試驗一）。

Table 3. Coefficients of linear correlation between checks plot yields and yield indices of plots with continuous slag application (Experiment 1).

crop \ year	No. Locations	1977	'78	'79	'80	'81	'82
1st	全部地點（9—10）		−0.69*	−0.54	−0.85**	−0.09	0.003
	去除壯圍一處		−0.85**	−0.83**	−0.86**	−0.72*	−0.35
2nd	全部地點（9—10）	−0.45	−0.45	−0.86*	−0.07	−0.52	
	去除壯圍一處	−0.70*	−0.72	−0.88**	−0.19	−0.65	

1）係1.5及3 t/ha區之平均

表4. 不同年度之矽酸爐渣連用區收量指數（1）與各地點對照區收量之直線相關（試驗一）。

Table 4. Coefficients of linear correlation between check plot yields and yield indices of plots with continuous slag application (Experiment 1).

Crop & year \ Location	樹林	壯圍	中壢	后里	埔里	民雄	後壁	屏東	高樹	9處平均
1st，1978−'82	−0.83	−0.46	−0.76	−0.85	−0.68	−0.73	0.64	−0.75	−0.78	−0.87*
2nd 1977−'81	−0.64	0.02	−0.96**	−0.75	−43	0.36	−0.56	−0.75	−0.65	−0.53

（1）係1.5及 3 t/ha 區平均

十處試驗地點中壯圍一處情況似較爲特殊，其試驗開始後之4作期間爐渣肥效很小，連用第5—8作期間轉爲顯著，但在連用第9—10作欲有下降趨勢。其連用爐渣6作後之停施區在第7及8作時亦一如其他試驗地表現爐渣殘效隨著時間之經過顯著的降低，但在第9及10作其殘效卻轉而增大，此點甚爲反常，尙待進一步觀察。

上述10處試驗地所表現之矽酸爐渣肥效，除壯圍一地較爲特殊外，可謂大體一致，其中龍潭一處早於69年2期起即停辦，故爲簡明起見乃將其餘九處試驗地的歷作平均示於圖2。

由圖2可見矽酸爐渣之肥效除了在其開始施用之第一作略低（1.5 及3公噸各區較對照區平均增產3.5及4.9%）外，5年間共9作之平均約略維持8～10%之增產效果。矽酸爐渣之肥效在其連用第8及9作（即70年1期及2期）時雖然顯著升高，惟相信此係與該作部份試驗地病蟲害較爲嚴重，致使對照區平均收量降低及矽酸爐渣之肥效增高有關，蓋上面也已經提過不同地點之矽酸爐渣肥效與各對照區收量常有顯著的負相關（表3）而不同年度之矽酸爐渣平均肥效與各對照區平均收量亦常有負的相關（第1、2期作相關係數各達−0.86及−0.53，圖4上）。。

試驗二，圖3實線部分亦示矽酸爐渣之增產效果非常顯著並在不同年度、期作有相當大的變異。由於不同年度之矽酸爐渣增產效果與各對照區收量亦有顯著的負相關（第1期作 r＝−0.82*，第二

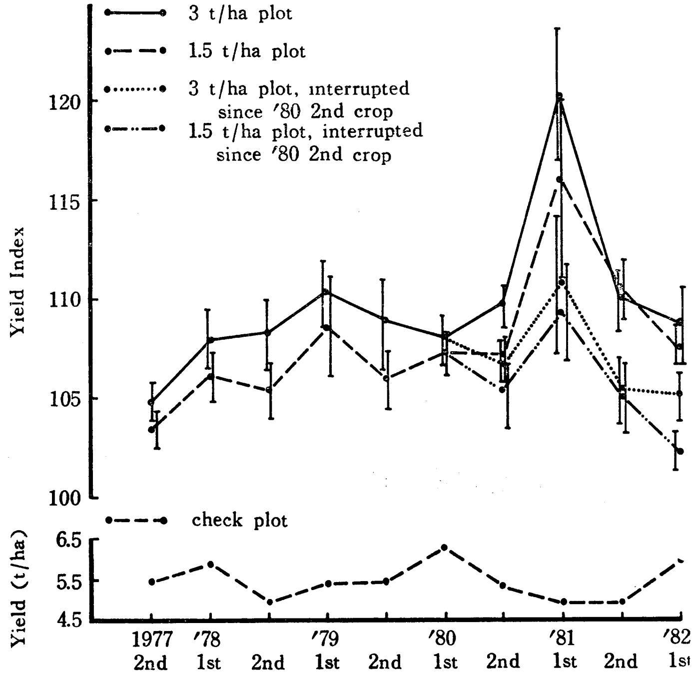


圖2. 歷作對照區之稻谷平均收量及矽酸爐渣連用區較對照區之收量指數*
（試驗一，9 處試驗平均）*附平均值之標準機差

Fig. 2. Check plot yields and yield indices of plots with continuous slag applications from 1977—1982. (Experiment 1, mean of 9 experimental locations and standard error of mean.)

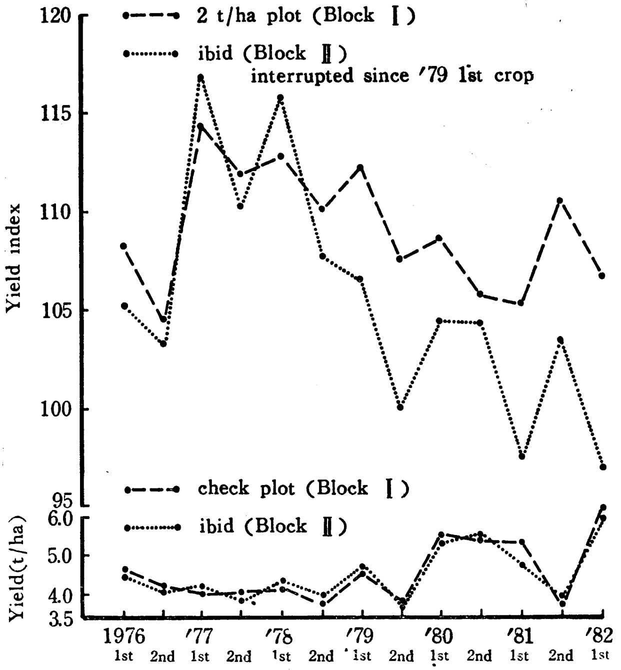


圖3. 歷作對照區之稻谷平均收量及矽酸爐渣連用區較對照區之收量指數（試驗二，中壢月眉里，每點均爲 6 重覆小區（即兩種主處理，稻藁之掩埋與否×各副處理 3 重覆）之平均。

Fig. 3. Check plot yields and yield indices of plots with continuous slag applications from 1976—1981. (Experiment 2).

期作 r＝－0.54，圖4下）故亦可以認定上述矽酸爐渣肥效在不同年度、期作之變異與其連用年數之累加無關。矽酸爐渣肥效與其連用年數之相關第1、2期作各爲－0.52及＋0.15，相關程度較小並正負不定。一般言之，第2期作之收量當較第1期作爲低，而水稻收量對矽酸爐渣之效應亦一如其對氮肥之效應一樣以收量較低之第2期作低於收量較高之第1期作。是故，吾人觀看圖2或圖3不同年度之對照區收量與矽酸爐渣增產指數之相關時如不將第1期與第2期作分開，將會有二者成正相關的幻覺。此與上面所指事實不符，應加注意。

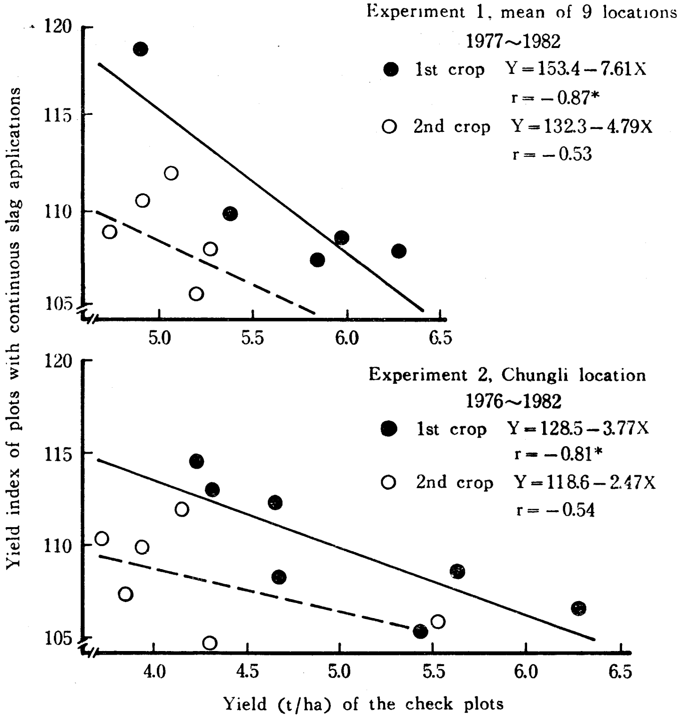


圖4. 不同年度之矽酸爐渣連用區收量指數（1）與各年度對照區收量之關係
（1）係1.5 及 3 t/ha 兩處理區之平均。

Fig. 4. Relationship between check plot yields and yield indices of plots with continuous slag application. Experiment 1: Mean of 9 experimental locations, 1977—1981. Experiment 2: 1976—1982.

由以上結果可以結論矽酸爐渣之肥效除了在其施用之初期略低外，連用期間其較對照區之增產率爐渣1.5及3噸區各在5～15及8～20％之間；矽酸爐渣肥效之不同年度變異主要係與對照區之收量有關（成負相關）而與爐渣連用年數之累加無顯著關係。亦即爐渣之連用雖達9～12作之多，尚看不出其對稻田生產力有任何不良影響，雖然同時亦看不出有繼續增進稻田生產力之顯著效果。

3.矽酸爐渣長期連用後對水稻之殘效：

試驗一矽酸爐渣每公頃每作1.5及3公噸各連用6作將各試區各劃分爲兩半，在第7、8及9作時其一半仍繼續施用爐渣，另一半則停施。結果（圖1及2點線部分）示停施者較續施者第7、8及9作稻谷收量指數平均各低落2.7，7.3及4.6％；矽酸爐渣之殘效依停施年數之增加而有顯然低落趨勢。試驗二矽酸爐渣連用6作後之停施（圖3點線部分）亦示爐渣殘效隨着停施年數而顯著降低之趨勢。

矽酸爐渣每公頃3公噸連用6作後其在土壤中之累積用量已甚可觀，但其停施者欲較續施者顯著減產，值得注意。

4.矽酸爐渣連用對若干土壤理化性質之影響：

由表5可見矽酸爐渣每公頃每作施用1.5及3公噸，經7作後表土之 pH 值平均各約提高 0.34 及0.84單位，而底土之 pH 值平均亦各提高0.44及0.63單位；表土之有效矽含量平均各約提高 130 及 300 ppm，但底土之有效矽含量平均卻僅提高各約 18 及 40 ppm 而已。可見所施爐渣中之鈣有大量自表土淋洗至底土跡象，反之。矽酸則否。矽酸之移動性顯然不大。

表5. 矽酸爐渣連用7作對若干土壤化學性質之影響（69年2期作收穫後，8處試驗地平均（1））

Table 5. Effect of continuous slag application (7 consecutive crops) on selected chemical properties of soil. (Mean of 8 experimental locations with standard error of mean. Soils were sampled at havest, 2nd crop 1980).

Rate of slag (t/ha/crop)	pH (1 : 1)		Available SiO_2 (ppm)		Organic matter (%)	Available (ppm)	
						P	K
	0—15 cm	15—30 cm	0—15 cm	15—30 cm	0—15 cm	0—15 cm	0—15 cm
0	5.13 ±0.15	5.88 ±0.30	51 ±10	70 ±17	2.90 ±0.33	64 ±14	36 ±4.0
1.5	5.47 ±0.14	6.32 ±0.26	182 ±28	88 ±17	2.90 ±0.32	58 ±15	35 ±3.3
3.0	5.97 ±0.21	6.51 ±0.26	359 ±42	111 ±19	2.93 ±0.32	62 ±15	38 ±3.7

Rate of Slag (t/ha/crop)	CEC (m. e./100g) 0—15 cm	Eych. (m. e./100 g)			Free Fe_2O_3 (%) 0—15cm	Eas redu Mn (ppm) 0—15 cm
		Ca 0—15 cm	Mg 0—15cm	K 0—15 cm		
0	6.69 ±0.72	3.83 ±0.77	0.83 ±14	0.075 ±0.009	1.45 ±0.33	8.26 ±2.56
1.5	6.61 ±0.73	4.16 ±0.64	0.86 ±0.12	0.065 ±0.010	1.56 ±0.44	11.58 ±2.73
3.0	6.79 ±0.74	4.57 ±0.79	0.93 ±0.11	0.071 ±0.010	1.53 ±0.40	14.16 ±4.04

（1）係壯圍、樹林、中壢、后里、埔里、民雄、屏東、高樹等地之平均，附平均值之標準機差。

矽酸爐渣連用7作後表土之可還原性錳含量亦較對照區顯著增高。至於其對土壤有機質，有效性磷、鉀等含量及置換性能量等則影響甚小。

矽酸爐渣1.5及 3 t/ha 各區，其繼續施用爐渣者第8及9作後之土壤 pH 值和有效矽含量約略維持與第7作時相同之水準，惟其停施者，其土壤 pH 值和有效矽含量則隨著停施之年數而有顯著下降

趨勢。矽酸爐渣每公頃每作連用 1.5 及 3 公噸達 6 作之久，其土壤中有效態矽酸之投入已非少量，惟其第 7 作時之停施欲立即反應於其土壤中之有效矽含量和稻藁中 SiO_2 含量之降低，除此之外，土壤中之易還原性錳及稻藁中之錳含量亦因矽酸爐渣之停施而略有減低趨勢（圖 5 及表 6）。

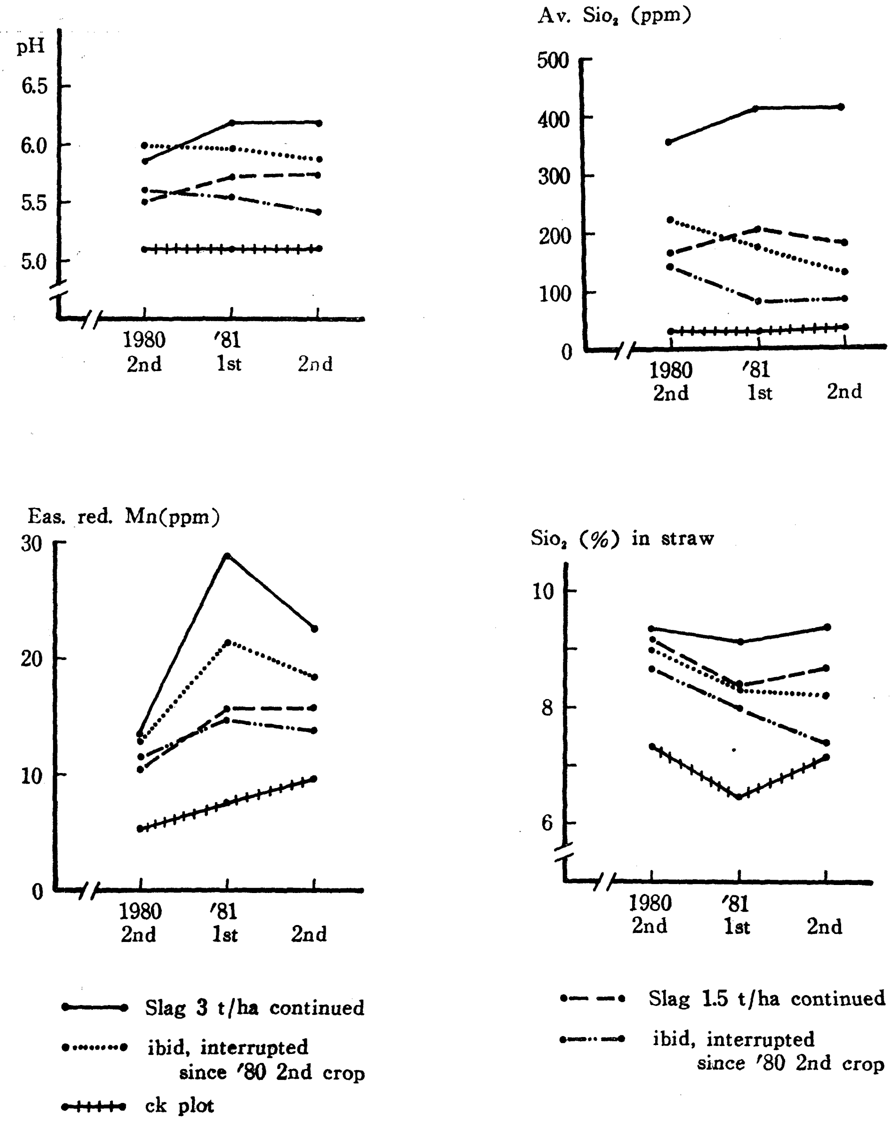


圖5. 矽酸爐渣連用 6 作後（即第 7 ～ 9 作時）之續施和停施對土壤 pH 值有效矽和易還原性錳含量及稻藁矽含量之影響（1）（69年 2 期～70年 2 期，收穫時）

Fig. 5. Effect of continuous and interrupted slag application of soil pH level, concentration of available silica and easily reducible Mn in the soil, and silica content of the rice straw on the 7th-9th crops, following 6 consecutive applications. (at harvest, 2nd crop 1980-2nd crop 1981).

（1）係中壢、后里、埔里、民雄 4 處試驗地之平均。土壤 pH 值，土壤有效矽含量和易還原性錳含量及稻藁矽含量，各平均值之標準機差，平均各爲0.22、0.51、6.3、0.62。

表6. 矽酸爐渣連用6作後（即第7作時）之停施較續施對水稻生育及要素含量之影響）
埔里，69年2期，插秧後40日）

Table 6. Effect on plant growth of continuous and interrupted slag application after 6 consecutive applications. (Pu-li, 40 days after transplanting, 2nd crop 1980, i. e., the 7th rice crop).

Rate of Slag t/ha/crop	Treatments	g/hill	%					ppm			
			SiO_2	N	P	K	Ca	Mg	Fe	Mn	Al
0	check	11.2	4.25	2.64	0.39	1.72	0.28	0.18	344	54	227
1.5	continued	14.5	5.85	2.64	0.45	1.72	0.32	0.18	308	98	251
	interrupted	12.1	5.45	2.74	0.46	1.62	0.30	0.18	352	75	287
3.0	continued	16.3	5.70	2.45	0.41	2.00	0.30	0.20	400	129	177
	interrupted	15.4	5.35	2.56	0.44	1.99	0.30	0.17	523	101	240

矽酸爐渣雖含有大量鋁，長期連用爐渣之土壤，置換酸度却較對照區土壤甚低，兩種土壤各經過大量稀鹽酸淋洗時連用爐渣之土壤較對照區土壤雖有多量鈣和矽洗出，鋁的洗出却無土壤間之顯著差異。連用爐渣的土壤經强烈的淋洗後，由於大量的鈣被洗出，其置換性鋁含量顯然增高，但並沒有超過對照區土壤，是故矽酸爐渣中所含的鋁並不值得憂慮。

表7. 矽酸爐渣連用土壤之置換酸度及淋洗後之置換性鋁含量（埔里，69年2期收穫後，曾經連用爐渣7作之土壤）。

Table 7. Exchangeable acidity of the soils with and without continuous slag application and exchangable aluminum of the soils after leaching. (Pu-li soil, at harvest, 2nd crop, 1980 after 7 consecutive crops of slag application)

Soils	Before leaching		After leaching	Major elements leached out (m. mole/100g)		
	PH (1：1)	Exch. acidity (me/100g)	Exch. Al (ppm)	Ca	Si	Al
Control (no slag applied)	4.5	0.99	121	0.70	1.07	4.37
With Slag (3 t/ha/crop)	5.2	0.13	124	2.17	2.64	4.30

5.矽酸爐渣連用土壤之有效矽收支估計：

假定矽酸爐渣中含有效矽（SiO_2）約20%則每公頃每作施用3公噸矽酸爐渣達7作等於施用有效矽4,200公斤／公頃。假定每公頃每作因施用爐渣3公噸而水稻吸收120公斤 SiO_2（以稻藁收量每公頃6,000公斤，並根據圖5施用爐渣後藁中 SiO_2 含量增高約2%計），則7作可吸收840公斤 SiO_2。因第7作收穫後之土壤測定結果示表底土中共累積有698公斤／公頃之有效矽（SiO_2）（以每公頃0—15及15—30公分土壤量各200萬公斤計算），故可回收之矽（即二者之和）只達1538公斤／公頃。因所施用之有效矽量已達4200公斤，可見所施有效矽之63%已被土壤固定或吸着，變爲不易被pH 4.0的規定醋酸鈉溶液萃取的形態（表8）。Khalid 氏等[20]探討夏威夷土壤中所施矽酸鈣的殘效亦指出所施矽酸之57～72%在其施後之5年間已被土壤固定。

表8. 矽酸爐渣連用7作後土壤中之有效矽收支估計
Table 8. Percentage of available SiO_2 in soil unaccounted for after 7 crops of continuous siliceous slag application.

Rate of slag application (t/ha)	1.5	3.0
Total available SiO_2 applied to soil for 7 crops (kg/ha)	2100	4200
Plant uptake of applied SiO_2 total from 7 crops (kg/ha)	546	840
Increase of available SiO_2 (kg/ha) in soil due to slag application at the end of the 7th crop	298	698
Percentage applied SiO_2 unaccounted for	60	63

由以上土壤中有效矽收支之估計及如前述矽酸爐渣雖連用多年其一作之停施却會立即反映於土壤中有效矽和稻藁中 sio_2 含量之降低一事，可見所施有效矽在土壤中之固定或無效化相當顯著。此或許就是矽酸爐渣需要繼續施用才能維持一定稻谷增産率或土壤肥力的原因。

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Effects of Long Term Application of Siliceous Slag on Paddy Yield and Chemical Properties of Soil

S. Lian and C. H. Wang[2]

Summary

Field experiments have been carried out island-wide at 9 paddy locations on acid soils for 5 years (10 crops) using 3 treatments: (1) check; no siliceous slag applied, (2) siliceous slag applied at the rate of 1.5t/ha/crop, and (3) siliceous slag applied at the rate of 3t/ha/crop. Nitrogen, phosphate and potash were amply applied to all of the test plots following the stantard recommended method. A randomized block design with two replications was adopted as the experimental procedure.

Beginning with the 7th crop, the plots with treatment (2) and (3) were each divided into two. One half of the plots received continuous siliceous slag applications while on the other, the application was interrupted, so that both the residual effect and the effect of continuous application could be observed.

Another experiment with and without the application of straw (0 and 5 t/ha/crop, respectively) as primary treatment, and with and without siliceous slag (0 and 2 t/ha/crop, respectively) as subtreatment was also conducted at one location for 6½ years (13 crops) Application of siliceous slag on half of these pltos was also interrupted beginning with the 7th crop for the same reason as above.

The results may be summarised as follows:

1. The yield responses to the slag application were generally high except at the beginning when the effect of slag seemed to be slightly lower. The yield increases in the plots with continuous slag applications of 1.5 and 3 t/ha/crop fluctuated in the ranges of 5—15 and 8—20%, respectively during the experimental period (Fig. 2 & 3). When crop yields were high, as represented by the check plot yield, response to the slag application was low, and vice versa. This means that there was a generally negative relationship between check plot yield and slag application response. (Table 3 & 4, and Fig. 4). Thus, these experiments do not yet give any clear indication that the slag has

any cumulative effect on the soil fertility (either positively or negatively) following continuous applications.

2. The residual effect of the slag was very significant soon after the interruption. Despite the previously continuous application of siliceous slag, the interruption resulted in an immediate decrease in the percentage of yield'increase compared to the plot with continuous application. Furthermore, the difference the grew greater as time lapsed after the interruption.

The residual effect remained higher in the plot where slag had been applied at the rate of 3t/ha/crop than in the plot where it had been applied at the rate of 1.5 t/ha/crop.

3. The continuous application of 1.5 and 3 t/ha/crop of siliceous slag on the first 7 crops resulted in total increases averaging 0.4 and 0.8 unit soil pH, and 130 and 300 ppm of available silica in the soil, respectively. These levels were maintained in the plot with the continuous application during the following crops, while they declined significantly once the application was interrupted. (Table 5 and Fig. 5)

About 60% of the sillica was either absorbed or disslpated in the soil, and was not readily extractable by the pH 4.0 acetate buffer solution.

(Table 8)

4. All of the above would seem to indicate that a continuous application of silice ous slag is beneficial for maintaining an increased level of soil fertility, since once the application is interrupted, the silica level in the soil, as well as the yield, decline. A lower, but continuous application would seem to be more effective than a higher rate of application which is interrupted for a long time. In prtacice, a continuous application at the rate of about 2t/ha on the first rice crop in each year can be recommended for the acid soils deficient in available silica.

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1. Contribution No. 1095 from Taiwan Agricultural Research Institute.

2. Soil scientist and assistant, respectively. Department of agricultural chemistry TARI. Wufeng, Taichung Hsien, Taiwan 431, ROC.

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